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Economic Impact Analysis of Pollution Control Technologies for Segments of the Inorganic Chemicals Manufacturing Industry

Energy and Environmental Analysis, Inc.
Arlington, VA

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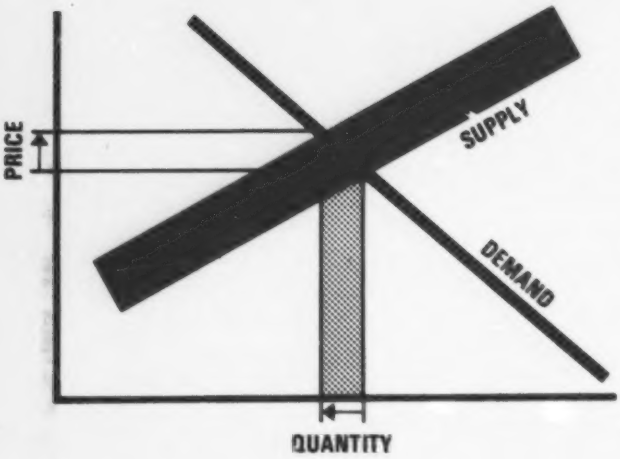

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The U.S. Environmental Protection Agency issued effluent guidelines and limitations for the Inorganic Chemicals Manufacturing Industry in July 1982. This report estimates the economic impact of pollution control costs in terms of price changes, effects on profitability, potential plant closures, unemployment, and other secondary effects. A model plant approach is used to assess these impacts for ten chemcial subcategories. In nine of the ten subcategories, impacts are minimal. For plants in the chrome pigments subcategory, price and profitability impacts are significant and production line closures are possible.

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Prepared for:

Office of Water Regulations and Standards
U.S. Environmental Protection Agency
Washington, D.C. 20460

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Stan Kaplan
Linda Marine
Project Managers

PREFACE

This document is a report of an economic contractor's study prepared for the Office of Analysis and Evaluation of the Environmental Protection Agency (EPA). The main purpose of the study is to analyze the economic impact of effluent control costs required to meet the BPT, BAT, PSES, NSPS, and PSNS guidelines established for the Inorganic Chemicals Manufacturing Point Source Category under the Federal Water Pollution Control Act. These guidelines were proposed on July 24, 1980 (Federal Register, Vol. 45, No. 144).

In addition, this study addresses potential impacts of the combined costs of compliance with effluent guidelines and the Interim Status Standards of the Resource Conservation and Recovery Act (RCRA-ISS) for segments of the inorganic chemicals industry which will incur both sets of compliance costs.

The investment and operating costs associated with effluent control treatment and RCRA-ISS requirements were developed by a technical contractor. The impact analysis included in this report is based on effluent control cost estimates as revised through March 1981 and on draft RCRA-ISS cost estimates developed in accordance with the "Draft Final Guidance Document for RCRA-ISS Costs" prepared by EPA's Office of Analysis and Evaluation in December 1980.

This study has been prepared with the supervision and review of the Office of Analysis and Evaluation of the EPA. This report is submitted in fulfillment of Contract No. 68-01-4618 by Energy and Environmental Analysis, Inc., and reflects work completed as of November 1981.

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A. EXECUTIVE SUMMARY

Introduction

The ultimate goal of the 1977 Clean Water Act (33 U.S. Code 1251) is to eliminate the discharge of pollutants into the nation's waterways by 1985. The Act states that this goal is the final step in a three step process. The two interim steps are:

1) The implementation, by July 1977, of the best practicable pollution control technology currently available (BPT) by all industries discharging into navigable waterways.
2) The implementation, by 1984, of the best available control technology economically achievable (BAT) for existing industrial direct dischargers.

The Environmental Protection Agency (EPA) was charged with the task of designing and enforcing regulations in an effort to realize the goals outlined in the Act.

The EPA is also required to establish new source performance standards (NSPS) for new industrial direct dischargers and pretreatment standards for new and existing dischargers to publicly owned treatment works (POTW's), called pretreatment standards for existing sources (PSES) and pretreatment standards for new sources (PSNS).

This document is an assessment of the likely economic impact of effluent limitations on ten chemical subcategories of the Inorganic Chemicals Industry. The subcategories are:

1. Aluminum Fluoride
2. Chlorine
3. Chrome Pigments

4. Copper Sulfate
5. Hydrogen Cyanide
6. Hydrogen Fluoride
7. Nickel Sulfate
8. Sodium Bisulfite
9. Sodium Dichromate
10. Titanium Dioxide

The purpose of this study is to analyze the economic impacts which could result from the costs of meeting effluent limitations in each of the above subcategories.

Organization of the Report

The report is divided into ten sections corresponding to the ten subcategories under study. Each section has two parts: Characterization and Impact Analysis. The characterization presents the recent history of the subcategory and the major forces (exclusive of effluent guidelines) that are shaping the future of the chemicals market. These include sales, changes in capacity, new processes, supply and demand characteristics, and the competitive structure of the subcategory.

After the industry baseline is described, the impact analysis employs a model plant approach to determine how effluent control costs will affect the subcategory.

Purpose

The purpose of this report is to examine the economic impacts of the costs of effluent control standards upon direct and indirect dischargers in ten subcategories of the Inorganic Chemicals Industry. The impacts studied are those that result from:

- Incremental costs incurred by direct dischargers to meet BAT limitations;

- Costs incurred by indirect dischargers currently not pretreating wastewater to achieve "pretreatment standards for existing sources" (PSES);
- Costs incurred by firms entering the industry to achieve standards set for new sources (NSPS and PSNS).

In addition, some of the subcategories included in this report will incur costs for compliance with the Resource Conservation and Recovery Act's Interim Status Standards (RCRA-ISS) promulgated in 1980. Accordingly, for the affected subcategories, the impacts of the combined effluent control and RCRA-ISS costs are examined.

Control technologies required to achieve EPA's effluent limitations were developed by a technical contractor. The technical contractor also developed RCRA-ISS cost estimates for plants in the affected subcategories.

Note that the RCRA-ISS costs developed for the analysis include baseline RCRA-ISS costs (i.e., costs that would be incurred even in the absence of effluent treatment) as well as the RCRA-ISS costs associated with the solid waste generated by effluent treatment systems. Therefore, these RCRA-ISS costs overstate the actual costs that will be required due to effluent regulations.

Methodology

The impacts of pollution control costs on the ten subcategories of the Inorganic Chemicals Industry are evaluated using a model plant approach. The methodology consists of 1) calculating a maximum price rise and profitability decline to define the range of potential impacts and 2) assessing the most probable economic impacts based on the most likely price increase, profitability decline, capital availability, and other relevant factors.

The price rise analysis assumes that pollution control costs can be fully passed through by increases in the product price and calculates the required product price rise necessary to recover the pollution control costs.

The profitability analysis assumes that the industry is unable to pass through any of the pollution control costs in the form of higher prices and increased costs are fully absorbed. The decreases in the return on investment (ROI) and internal rate of return (IRR) are calculated under this assumption. These profitability measures are based upon estimated manufacturing costs and the technical contractor's pollution control costs.* They are not meant to precisely quantify the actual returns experienced at each plant.

The price elasticity of demand is estimated subjectively based on the information developed in the characterization section. (Important economic information for each section is summarized in Table A-1.) The elasticity estimate (low, medium, high) suggests the probability of an immediate and complete price increase to recover pollution control costs.

The capital ratio characterizes the pollution control investment in comparison to investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. Model plants with a maximum price rise less than one percent, a maximum profitability decline of less than one percentage point and less than ten percent of baseline profitability, and relatively inelastic demand are considered low impact cases that do not require further detailed analysis. If price and profitability impacts are significant, a further investigation is made into potential plant closures,

---

*An economic subcontractor developed the manufacturing costs.

TABLE A–1
SUMMARY OF ECONOMIC CHARACTERISTICS

			CHEMICAL SUBCATEGORY										
			Aluminum Fluoride	Chlorine-Mercury	Chlorine-Diaphragm	Chrome Pigments	Copper Sulfate	Hydrogen Cyanide	Hydrogen Fluoride	Nickel Sulfate	Sodium Bisulfite	Sodium Dichromate	Titanium Dioxide
SUPPLY	1977 Production Volume[a]		Low 148,500	High 10,500,000		Low-1976 71,000	Low 31,100	Low 197,900	Low 278,000	Low 7,000	Low[j] 100,000	Low 156,300	High 720,000
	Number of Producers		4	12	23	12	11	9	6	10	4	3	6
	Number of Plants		5	26[g]	36[g]	12	16	12	9	11	7	3	13
	Product Concentration[b]		$CR_2=76$	$CR_1=30$	$CR_6=71$	–	$CR_3=90$	$CR_2=43$	$CR_3=80$	$CR_2=60$	$CR_2=74$[j]	$CR_2=83$	$CR_1=55$
	Capacity Utilization[c]		Low 59%	Medium 67–75%		Medium 78%	Low 63%	Low 65%	High 83%	Low 71%	Low 62%	Medium 77%	Medium 76–77%
	Significant Integration[d]	Backward	Yes	Yes		No	Yes	Yes	No	No	Yes	No	Yes
		Forward	Yes	Yes		No	No	Yes	Yes	Yes	No	No	Yes
DEMAND	End Market Concentration[e]		High (NA)	$EMC_1=17$		Low (NA)	$EMC_1=42$	$EMC_1=60$	$EMC_1=42$	$EMC_1=90$	$EMC_1=50$	$EMC_1=29$	$EMC_1=51$
	Average Annual Growth Rates 1968–1977	Production	0.7%	2.5%		0.86%	–4.1%	3.0%	–0.9%	–7.2%	5.5%	0.8%	1.6%
		Price	10.5%	8.1%		9.0%[h]	6.4%	NA	14.7%	11.1%[i]	10.4%	9.9%	5.4%
COMPETITION	1977 Imports[f]		High 3%	Low (NA)		High 3%	High 10%	Low (NA)	High (NA)	Low (NA)	Low (NA)	Low (NA)	High 15%
	1977 Substitutes		Negligible (cryolite)	Few		Few (organic pigments)	Many (organic fungicides)	Few	Many Secondary	Many Secondary	Negligible	Negligible (sodium chromate)	

NOTES:

[a] PRODUCTION VOLUME: Low is less than 300,000 tons; medium is 300,000 to 600,000 tons; high is greater than 600,000 tons.

[b] PRODUCTION CONCENTRATION ($CR_x=Y$): Where CR is a concentration ratio; x is the number of producers; Y is the percent of total production.

[c] CAPACITY UTILIZATION: Chemical industry's average is 75%. Capacity utilization is the percent of nameplate(official) capacity actually in use for a given period of time. Low is less than 70%; medium is 70 to 79%; high is greater than 80%.

[d] INTEGRATION: Backward indicates producers manufacture of raw materials; forward is producers manufacture of end products.

[e] END-MARKET CONCENTRATION ($EMC_x=Y$): Where EMC is a use ratio; x is the number of markets; Y is the percent of total production going to this/these market(s).

[f] IMPORTS: Percent of total U.S. production, where low is less than 2%; medium is 2 to 7%; high is greater than 7%.

[g] Five plants produce chlorine by both processes.

[h] Chrome yellow and orange only.

[i] Growth from 1967 to 1975.

[j] Estimated.

NA: Information not available.

SOURCES: Development Document, June 1980. Department of Commerce, 1977. Industry sources.

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unemployment, community impacts, industry expansion effects, and other secondary impacts.

Economic Impacts

Tables A-2a and A-2b summarize the potential impacts for each chemical subcategory. Table A-2a summarizes the costs and potential plant closures associated with PSES limitations (for indirect dischargers) and BAT limitations (for direct dischargers). Total investment and annualized costs of pollution control are presented for the affected plants in each subcategory.

Table A-2b summarizes the price and profitability impacts of effluent control costs. The table presents the range of price impacts assuming full price pass-through necessary for the model plants to completely recover pollution control costs and the profitability impacts assuming no pass-through as measured by changes in the ROI and IRR in each subcategory.

In nine of the ten subcategories, impacts were found to be minimal. For plants in the chrome pigments subcategory price and profitability impacts are significant and plant production line closures are possible.

The total annualized costs of compliance with PSES limitations required for the 8 indirect dischargers currently not pretreating wastewater are estimated to be approximately $7.1 million. Total investment costs required to meet PSES limitations are estimated to be $8.7 million. The largest costs and, therefore, the most severe impacts of compliance with PSES limitations are incurred by plants in the chrome pigments subcategory. As shown in Table A-2a, two production line closures are possible in the chrome pigments subcategory.

TABLE A–2a

SUMMARY OF IMPACTS: COSTS AND CLOSURES

IMPACTS		Aluminum Fluoride	Chlorine-Mercury	Chlorine-Diaphragm	Chrome Pigments	Copper Sulfate	Hydrogen Cyanide	Hydrogen Fluoride	Nickel Sulfate	Sodium Bisulfite	Sodium Dichromate	Titanium Dioxide-Sulfate	Titanium Dioxide-Chloride	Titanium Dioxide-Chloride Ilmenite	TOTAL
		CHEMICAL SUBCATEGORY													
	Total Number of Plants Affected	5	25	36	12	16	7	9	11	7	3	4	6	3	144
PSES	Plants Incurring Costs	0	0	1	5	0^{3}	0	0	0^{3}	1^{4}	0	1	0	0	8
	Total Annualized Costs	NA	NA	570,580	4,992,500	NA	NA	NA	NA	92,337	NA	1,475,920	NA	NA	7,131,337
	Total Investment Costs	NA	NA	909,000	6,379,435	NA	NA	NA	NA	144,174	NA	1,225,950	NA	NA	8,658,568
	Potential Plant Closures	NA	NA	0	2^{2}	0	NA	NA	0	0	NA	0	NA	NA	2
BAT	Plants Incurring Costs	0^{1}	23	35	2	0^{1}	6	9	0^{1}	0^{1}	0^{1}	2	0^{1}	0^{5}	77
	Total Annualized Costs	NA	1,348,220	4,053,440	780,770	NA	713,489	377,876	NA	NA	NA	6,457,872	NA	NA	13,761,667
	Total Investment Costs	NA	1,276,638	3,893,670	1,418,811	NA	1,237,170	774,180	NA	NA	NA	5,345,454	NA	NA	13,945,923
	Potential Plant Closures	NA	0	0	0	NA	0	0	NA	NA	NA	0	NA	NA	0
BAT plus PSES	Plants Incurring Costs	0^{1}	23	36	7	$0^{1,3}$	6	9	$0^{1,3}$	$1^{1,4}$	0^{1}	3	0^{1}	0	85
	Total Annualized Costs	NA	1,348,220	4,624,020	5,776,270	NA	713,489	377,876	NA	92,337	NA	7,933,792	NA	NA	20,863,004
	Total Investment Costs	NA	1,276,638	4,802,670	7,798,246	NA	1,237,170	774,180	NA	144,174	NA	6,571,413	NA	NA	22,604,491
	Potential Plant Closures	NA	0	0	2^{2}	0	0	0	0	0	NA	0	NA	0	2

NOTE: All Costs are in Mid-1978 Dollars.

FOOTNOTES TO TABLE A-2a

1/ For this subcategory, BAT is equivalent to BPT. Since BPT is in place and operating for all direct dischargers, there will be no incremental costs over BPT required for compliance with BAT limitations.

2/ Line closures. Impacted plants produce other products and will likely continue to do so.

3/ Indirect dischargers will not incur any control costs under this rulemaking.

4/ The control system for this subcategory is oversized. The control costs and impacts are therefore overstated.

5/ All plants are currently achieving removal levels equivalent to BAT limitations.

TABLE A–2b

SUMMARY OF PRICE AND PROFITABILITY IMPACTS

IMPACTS		CHEMICAL SUBCATEGORY													TOTAL
		Aluminum Fluoride	Chlorine-Mercury	Chlorine-Diaphragm	Chrome Pigments	Copper Sulfate	Hydrogen Cyanide	Hydrogen Fluoride	Nickel Sulfate	Sodium Bisulfite	Sodium Dichromate	Titanium Dioxide-Sulfate	Titanium Dioxide-Chloride	Titanium Dioxide-Chloride Ilmenite	
	Total Number of Plants Affected	5	25	36	12	16	7	9	11	7	3	4	6	3	144
PSES	Plants Incurring Costs	0	0	1	5	0^3	0	0	0^3	1^4	0	1	0	0	8
	Range of Required Price Rise	NA	NA	2.2%	5.54–14.03%	NA	NA	NA	NA	8.97%	NA	2.11%	NA	NA	
	Probability of Price Pass-Through	NA	NA	High	Low	NA	NA	NA	NA	High	NA	Low	NA	NA	
	Range of Potential Percentage Point Profitability Declines	NA	NA	0.43	9.79–17.92	NA	NA	NA	NA	5.41	NA	0.75	NA	NA	
	(Percent Decline)			(3.9%)	(38.08–163.50%)					(64.02%)		(6.86)			
	Potential Plant Closures	NA	NA	0	2^2	0	NA	NA	0	0	NA	0	NA	NA	2
BAT	Plants Incurring Costs	0^1	23	35	2	0^1	6	9	0^1	0^1	0^1	2	0^1	0^5	77
	Range of Required Price Rise	NA	0.36–1.54%	0.47–2.01%	8.63–14.03%	NA	0.67–0.81%	0.19–0.34%	NA	NA	NA	9.52%	NA	NA	
	Probability of Price Pass-Through	NA	High	High	Low	NA	High	High	NA	NA	NA	Low	NA	NA	
	Range of Potential Percentage Point Profitability Declines	NA	0.06–0.21	0.10–0.25	11.67–17.92	NA	0.25–0.27	0.15–0.52	NA	NA	NA	4.64	NA	NA	
	(Percent Decline)		(0.44–24.42%)	(0.95–8.96%)	(56.68–163.50%)		(1.01–1.24%)	(0.87–11.61%)				(61.62%)			
	Potential Plant Closures	NA	0	0	0	NA	0	0	NA	NA	0	0	NA	NA	0

NOTE. All costs are in Mid-1978 dollars.

FOOTNOTES TO TABLE A-2b

1/ For this subcategory, BAT is equivalent to BPT. Since BPT is in place and operating for all direct dischargers, there will be no incremental costs over BPT required for compliance with BAT limitations.

2/ Line closures. Impacted plants produce other products and will likely continue to do so.

3/ Indirect dischargers will not incur any control costs under this rulemaking.

4/ The control system for this subcategory is oversized. The control costs and impacts are therefore overstated.

5/ All plants are currently achieving removal levels equivalent to BAT limitations.

For the 122 direct dischargers, the incremental costs of compliance with BAT limitations were determined to have no severe impacts in any of the ten subcategories. Incremental costs will be incurred by 77 plants in order to comply with BAT limitations. Total annualized costs for these direct dischargers are estimated at approximately $13.8 million, with their investment in pollution control equipment estimated at $13.9 million.

The combined incremental costs of compliance with effluent limitations and RCRA-ISS requirements* are estimated for two subcategories. In the chrome pigments subcategory plant closures are possible. However, the incremental costs of RCRA-ISS compliance were not found to result in additional plant closures; rather, the number of plant closures projected is the same as that projected as a result of effluent control costs alone.

In assessing the potential impacts of pollution control costs on each of the ten subcategories, the following generalizations can be made:

- The costs of achieving first level control costs (BPT or base level pretreatment) are much higher than the incremental costs above BPT required to meet BAT limitations. Therefore, for subcategories where all plants currently have BPT and pretreatment systems in place, economic impacts of incremental effluent control costs are very small (e.g., hydrogen cyanide). For subcategories in which plants do not have base level treatment systems installed, potential economic impacts are much higher (e.g., chrome pigments).

- Operating costs (the annual cost of labor, chemicals, and maintenance required to operate the pollution control equipment) will be more burdensome than investment costs in almost every subcategory. Operating costs will rise over time with other manufacturing costs, while investment costs are a one time cash outlay. The ratio of investment costs to operating costs ranges from a low of 1.0 (for hydrogen cyanide) to 4.39 (for nickel sulfate) with most subcategories having a ratio of two to three.

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*Note that the RCRA-ISS estimates overstate the costs associated with effluent limitations because they include baseline RCRA costs as well as the costs associated with solid wastes generated by effluent treatment. However, since the overstated costs resulted in no significant incremental impacts, baseline and after-effluent control RCRA costs were not separated in the analysis.

- Impacts, as measured by maximum price rise and profitability decline, were generally more pronounced in the smallest model plant in each subcategory. This results from most subcategories experiencing economies of scale in both the effluent removal systems and in manufacturing costs.

Total revenues for the subcategories were $2.5 billion dollars in 1977, or 0.13 percent of the Gross National Product. The total incremental annualized costs of meeting BAT and PSES limitations (estimated at $20.9 million in mid-1978 dollars) represent less than one percent of total industry revenues. Since the costs are a small percentage of revenues, the impact on inflation would be very slight.

The impact analysis suggests that two plants will close chrome pigments production lines as a result of pollution control costs, affecting approximately 60 employees.

There should be minimal balance of payments impacts since most inorganic chemicals are low value products serving regional markets. The exceptions are titanium dioxide, copper sulfate and hydrogen fluoride. Only titanium dioxide has a large enough world market to warrant an analysis of potential balance of payments impacts. However, no consequential impacts are expected to result from effluent regulations.

New source performance standards (NSPS) and pretreatment standards for new sources (PSNS) are not expected to significantly discourage entry or result in any differential economic impacts on new plants in the inorganic chemicals industry. The pollution control capital investment required to install a given treatment technology is the same for new and existing producers in the industry. Therefore, at a given level, new plants will not be operating at a cost disadvantage relative to current manufacturers.

Immediately following is a brief summary of the impacts of effluent control costs on each subcategory. This section concludes with a brief summary of the incremental impacts of RCRA-ISS costs for the affected subcategories.

1. Aluminum Fluoride

For this subcategory, no incremental costs will be incurred to comply with BAT limitations. BAT is equivalent to BPT and BPT is in place and operating for the five plants (all direct dischargers) in the subcategory. The following characterization data is presented for informational purposes only.

Over 90 percent of aluminum fluoride is utilized in the production of primary aluminum. Hence the profitability, growth and production of the aluminum industry determine the demand for aluminum fluoride. The aluminum industry is presently restraining capacity expansion in an effort to increase capacity utilization. This will reduce growth in aluminum fluoride demand. Decreased demand growth will also result from EPA fluoride emissions standards which have resulted in increased fluoride recovery and recycling among aluminum manufacturers.

In the merchant market, the price of aluminum fluoride is likely to remain low due to vigorous intra-industry competition. This, coupled with rising manufacturing costs, will keep profit margins low.

2. Chlorine

Because chlorine is a critical input for several processes, many producers make it for their own use (captive production is over 60 percent of total production). Chlorine's end markets are experiencing varying growth rates. Overall, demand for chlorine is expected to parallel GNP growth.

Almost all chlorine is manufactured using one of two processes covered in this study: diaphragm cell (74% of production) and mercury cell (20% of production).

Rising costs, due to government regulations other than effluent guidelines and increased electricity prices, have combined with soft prices (the result of industry overcapacity) to strain industry profitability. However, chlorine's profitability is determined by the profitability of its end products, since almost two thirds is used captively in the manufacture of construction materials. Demand for chlorine in most end markets is expected to remain strong enough to justify continued chlorine manufacture.

The economic effects of pollution control requirements were analyzed in terms of four indicators:

- Price Rise (all pollution control costs passed through to consumers): for the one indirect discharger in the subcategory without treatment in place, the required price increase to recover pretreatment costs is 2.2 percent. For direct dischargers, the maximum price increase for either mercury cell or diaphragm cell producers is 2.01 percent.

- Profitability Decline (all pollution control costs absorbed by the firm): the decline in profitability for both processes and for direct and indirect dischargers is less than 0.6 percentage points (as measured by ROI) in all cases. For the two large model plant sizes, this decline reflects less than a five percent decrease in profitability from the base case. However, for the smallest model plant size, profitability decreases 24.42 percent for the mercury cell process and 8.96 percent for the diaphragm cell process (based on ROI).

- Price Elasticity of Demand: assumed inelastic since 1) there are no direct substitutes for chlorine in many end uses; 2) most chlorine production is used captively; and 3) cost increases can be passed on through price increases for various downstream products.

- Capital Ratio (pollution control capital costs as a percentage of fixed investment): capital costs for technology required for pretreatment by the one indirect discharger represent slightly over one percent of fixed investment. Additional capital costs for BAT effluent limitations are only a fraction of one percent of fixed investment for all plants.

Chlorine manufacturers using most of their production captively in other downstream products should have little difficulty recovering pollution control costs through price increases for final products. The facilitated price pass-through should prevent any profitability decline of the magnitude projected for the small model size mercury cell plant. Merchant producers may be unable to implement a complete and immediate price rise of three percent and may suffer a short term decline in profits. However, this profitability decline will not be of sufficient magnitude or duration to seriously injure the industry.

3. Chrome Pigments

The chrome pigments subcategory is made up of chrome yellow and orange, chrome green, chrome oxide green, molybdate chrome orange, and zinc yellow. The profitability of the producers of lead-containing chrome pigments is in doubt. Profitability will depend upon the ultimate costs of meeting the OSHA regulations and the extent to which these costs can be passed through in the form of higher prices. Demand forecasts range from zero growth, at best, to a substantial decline in demand.

Two plants in this subcategory are currently meeting effluent limitations. Three small indirect dischargers (2200 tons or less of annual production) will be exempt from regulation. The remaining seven plants (two direct dischargers and five indirect dischargers) will incur additional effluent control costs to meet BAT/PSES limitations. The economic effects of these effluent control costs were analyzed in terms of four indicators:

- Price Rise (all pollution control costs passed through to consumers): the price rise required to pass through the costs of PSES/BAT control ranges from 5.5 to 14.0%.
- Profitability Decline (all pollution control costs absorbed by the firm): absorbing the costs of BAT/PSES removal would result in a decline in profitability of almost 18 percentage

points (as measured by ROI) for the smallest plant. The decline represents a decrease in profitability of over 100 percent from the base case. The other three models experience declines in IRR ranging from ten to 12 percentage points or 26 to 57 percent of baseline profitability.

- Price Elasticity of Demand: assumed to be moderately elastic. While organic substitutes are much more expensive than inorganic pigments, lower priced imports may constrain domestic price increases.
- Capital Ratio (pollution control capital costs as a percentage of fixed investment): capital costs required of all model plant sizes to meet effluent regulations represent a serious cost hurdle: approximately one-third of fixed investment.

Smaller chrome pigment plants are operating close to the breakeven point and the profitability decline is likely to encourage them to cease operations. An examination of the two non-exempt plants that fall into this "small" category suggests that one may close its chrome pigments production line. One medium-size plant production line closure may also occur within the next five years. These projected line closures will affect 60 employees. Note that the closure projections are in reference to chrome pigments production only. The affected plants produce other products, and it appears likely that only the chrome pigment production line, which accounts for a small part of plant production, would shut down.

4. Copper Sulfate

For this subcategory, BAT and PSES are equivalent to BPT. All plants except one indirect discharger are currently in compliance with BPT. The costs the remaining plant will incur are associated with pre-treatment standards already in effect, not the current rulemaking. Therefore, the BAT/PSES compliance costs for this industry are zero. The following economic data is provided for informational purposes only.

Copper sulfate is a low volume chemical with a variety of applications in agriculture and industry. Domestic production of copper sulfate has declined dramatically over the last 25 years, due to a worldwide shift away from copper sulfate as an agricultural fungicide. The once large export market for copper sulfate is now nonexistent. However, a recent upturn in copper sulfate sales has resulted in some industry optimism.

In 1977, imports captured nearly 10 percent of the copper sulfate market. Low priced imports have forced domestic producers to sell copper sulfate at less than published list prices in certain markets to remain competitive. Rising copper prices, combined with strong competition from imports and substitutes, may cause profit margins to decline in the near future.

5. Hydrogen Cyanide

Hydrogen cyanide (HCN) is a highly toxic chemical used as an intermediate in the production of plastics, herbicides, and fibers. The hydrogen cyanide industry is characterized by a high degree of captive use: over 90 percent is used by the manufacturers in the production of "downstream" chemicals.

The major end use of hydrogen cyanide is in the production of methyl methacrylate (MMA). MMA is polymerized to yield a durable plastic which is used in a number of markets. A new, less costly, production process has been developed that does not utilize HCN, and a number of companies are considering adopting this new technology. The rate of adoption of this new technology will determine future HCN demand.

Since HCN is almost entirely a captive input for production of other chemicals, its profitability is determined by the profitability of its end products. Most of these end products are currently produced profitably. However, use of HCN is expected to decline due to the adoption of the new MMA technology.

The economic impacts of pollution control costs were analyzed in terms of four indicators:

- Price Rise (all pollution control costs can be passed through to consumers): the increase in price needed to recover the incremental cost of BAT treatment is less than one percent for all model plant sizes.

- Profitability Decline (all pollution control costs absorbed by the firm): should producers be unable to pass on the cost increases in higher downstream product prices, the decline in profitability would be roughly one-fourth of one percentage point of the IRR or less than 1.25 percent of baseline profitability for each model plant size.

- Price Elasticity of Demand: assumed inelastic due to high captive use and the inelastic demand for downstream products.

- Capital Ratio (pollution control capital costs as a percentage of fixed investment): in all model plant sizes, the capital required for pollution control is one-half of one percent or less of fixed investment.

The small increase in HCN cost could be easily passed on in higher downstream product prices. The demand outlook for all products which require HCN in their manufacture is sound enough to sustain the small increase. The potential profitability decline is so slight that it is not likely to give captive producers of HCN increased incentive to adopt new manufacturing technologies, not dependent upon HCN.

6. Hydrogen Fluoride

Hydrogen fluoride (HF) has two main end uses: primary aluminum production and fluorocarbon production. Demand in these markets is declining. In the aluminum market, the decline is a result of extensive fluoride recovery efforts by the aluminum manufacturers. The fluorocarbon end market also has experienced severe cutbacks due to the EPA and FDA ban on fluorocarbons in aerosols. In addition, the Environmental Protection Agency is considering regulation of all fluorocarbon uses, which would be another setback for the industry.

The profitability of the hydrogen fluoride industry is dependent upon the resolution of the uncertain demand factors in aluminum production and fluorocarbon applications. Most of the reduction in HF demand will be in captive uses. The merchant market is not expected to suffer, as long as aluminum manufacturers shut down excess capacity rather than sell HF on the merchant market.

The economic effects of pollution control requirements were analyzed in terms of four indicators:

- Price Rise (all pollution control costs passed through to consumers): passing on the incremental costs of BAT treatment requires a price increase significantly less than one percent for all model plant sizes.
- Profitability Decline (all pollution control costs absorbed by the firm): absorbing the costs of BAT treatment would cause a decline in IRR of one half of one percentage point or less for all model plant sizes. For the two larger model plant sizes, this represents less than 1.3 percent of the baseline profitability. The small model plant size profitability decreases 11.61 percent.
- Price Elasticity of Demand HF demand is assumed to be moderately price elastic due to imports' constraint on domestic prices.
- Capital Ratio (pollution control capital costs as a percentage of fixed investment): the additional capital requirements for BAT are minimal, representing only 0.6 percent of fixed investment in all cases.

The price and profitability impacts of compliance with BAT limitations are small for the two larger model plant sizes. Though profitability of the small model plant size decreases 11.61 percent, the maximum price rise required is small (less than one percent). Therefore, no plant closures or secondary impacts are anticipated for this subcategory.

7. Nickel Sulfate

For this subcategory, BAT and PSES are equivalent to BPT. All plants except two indirect dischargers are currently in compliance with BPT. The costs the remaining plants will incur are associated with pre-treatment standards already in effect, not the current rulemaking. Therefore, the BAT/PSES compliance costs for this industry are zero. The following economic data is provided for informational purposes only.

Nickel sulfate is a low volume chemical used primarily in metal plating. Total production of nickel sulfate has declined from a high of about 21,000 short tons in 1970 to 7,032 tons in 1977. Recycling efforts and substitution of other materials will cause nickel sulfate production to continue declining for the next few years. Profitability in the nickel sulfate industry has been marginal in recent years and is expected to erode still further due to declining sales, competitive pricing policies and rising nickel costs. However, manufacturers are expected to continue producing nickel sulfate to offer customers a complete line of electroplating chemicals.

8. Sodium Bisulfite

Sodium bisulfite is used in photographic processing, food processing, tanning, textile manufacture, and water treatment. The principal markets for sodium bisulfite should provide steady demand for sodium bisulfite as they are well developed and secure. The two largest sodium bisulfite manufacturers account for most of industry sales. Prices have always been strong and producers have typically not offered discounts on list prices.

Producers of sodium bisulfite have maintained strong profit margins by successfully increasing prices as manufacturing costs rose. Based on the past performance of the industry, future manufacturing cost increases are likely to be passed through and profit margins are expected to remain intact.

Only one plant, an indirect discharger, will incur incremental effluent control costs. For direct dischargers, BAT is equivalent to BPT and BPT is in place and operating for all direct discharge plants. The economic effects of pollution control requirements for the one plant incurring costs were analyzed in terms of four indicators:

- Price Rise (all pollution control costs passed through to the consumer): the price increase required to pass on pretreatment costs is 8.97 percent.

- Profitability Decline (all pollution control costs are absorbed by the firm): the maximum potential profitability decline resulting from absorbing pretreatment costs is 5.41 percentage points or 64 percent of the baseline profitability (as measured by ROI) for the model representing the affected plant.

- Price Elasticity of Demand: assumed inelastic since there are no close substitutes for sodium bisulfite in its major end markets.

- Capital Ratio (pollution control capital costs as a percentage of fixed investment): the capital investment required for pretreatment is 6.9 percent of fixed investment for the affected plant.

The price rise required for the affected sodium bisulfite plant is high, almost nine percent. However, given that sodium bisulfite demand is inelastic and that the affected plant enjoys a regional market advantage as one of only two sodium bisulfite producers on the West coast, price pass-through should be possible. Further, unlike all other sodium bisulfite plants, this plant is currently not incurring effluent control costs.

Therefore, it must be assumed the the plant has been operating at a cost advantage and that pretreatment costs will bring its costs in line with current cost levels experienced by the other plants already operating effluent control equipment. Thus the impacts of pretreatment costs on the sodium bisulfite subcategory are minimal.

9. Sodium Dichromate

All plants are currently in compliance with BPT limitations. For this subcategory, BAT is equivalent to BPT. Therefore no incremental costs will be incurred to comply with BAT limitations. The following characterization data is presented for informational purposes only.

Sodium dichromate (or sodium bichromate) is the principal source of chromium for a variety of applications, including chrome pigments, tanning agents, and wood preservatives. Sodium dichromate has relatively secure end markets with few substitutes. Industry observers cite possible OSHA regulations on worker exposure to hexavalent chromium as a potential threat to growth in dichromate's main market, chromic acid. If demand cutbacks due to OSHA regulations are not severe, growth should average two to three percent annually and profit margins should remain secure.

10. Titanium Dioxide

Titanium dioxide (TiO_2) is a white pigment used to whiten or opacify paints, paper, plastics, and several other products. It is a well established, mature product having been produced for over 40 years. Most of its many end markets are also mature, so demand growth is expected to parallel GNP growth. Three processes are used to manufacture titanium dioxide: the sulfate process, the chloride process, and the chloride-ilmenite process. Chloride process plants are currently meeting BAT limitations. Similarly, all three chloride-ilmenite plants are achieving removal levels equivalent to BAT limitations and will incur no additional effluent control costs. Therefore, the impacts of effluent control costs are addressed only for sulfate process titanium dioxide producers.

Many titanium dioxide manufacturers incurred losses for several months prior to mid-1978. The competitive pressures of imports and DuPont's low cost chloride-ilmenite process have restrained prices. Future profitability for most producers will depend on strong demand and, in the long run, utilization of lower cost technologies.

There are four sulfate process plants. One plant has BPT equipment in place and operating. For this subcategory, BAT is equivalent to BPT. Therefore, only three plants will incur additional effluent control costs.

The economic effects of effluent control costs on sulfate plants were analyzed in terms of four indicators:

- Price Rise (all pollution control costs passed on to the consumer): The price rise required to pass through PSES/BAT costs ranges from 2.11 to 10.11 percent.
- Profitability Decline (all pollution control costs absorbed by the firm): The profitability decline resulting from BAT/PSES is large. The maximum potential decline in IRR ranges from 0.75 to 4.64 percentage points or 6.86 to 61.62 percent of baseline profitability.
- Price Elasticity of Demand: assumed highly elastic since sulfate process price increases are constrained by imports and lower cost domestic producers.
- Capital Ratio (pollution control capital costs as a percentage of fixed investment) capital required to install BAT/PSES control represents 0.08 to 3.17 percent of fixed investment.

One of the actual sulfate process plants incurring effluent control costs corresponds to model size 3. For this plant, closure is very unlikely because the profitability decline from absorbing all control costs is minimal. Also, the plant is currently ocean dumping part of its waste stream at a cost significantly below the cost of physical/chemical wastewater treatment. This plant may incur additional pretreatment costs for the portion of its effluent being discharged to a POTW. Given that the plant will be allowed to continue ocean dumping through at least 1989, its wastewater treatment costs will be lower than the costs of a total land-based treatment facility. In this case, it seems unlikely that the plant would choose to close.

The remaining two producers correspond to the small model size. The model plant analysis indicates substantial price and profitability impacts for this size category. However, one of these two small producers has already made a partial investment in waste treatment facilities which is not reflected in the analysis; therefore, the price and profitability impacts for this plant are overstated. Moreover, despite the additional costs that would be incurred to reach full compliance, the producer has publicly announced that it plans to continue production and foresees a long-term market for the anatase grade pigment produced by the sulfate process (Chemical Marketing Reporter, December 24, 1979). The final regulation also incorporates specific changes requested by this manufacturer. Given these circumstances, it seems unlikely that the plant would close.

The other plant has recently signed a court agreement to meet limitations equal to those set forth in this final regulation and has agreed to install wastewater treatment controls and continue production in compliance with the regulation. Accordingly, continued operation of the plant appears likely.

In summary, although the quantitative economic indicators suggest possible closure of these two plants, their actual circumstances are such that closures appear highly unlikely.

Incremental Impacts of RCRA-ISS Costs

Table A-3 summarizes the incremental impacts of RCRA-ISS costs* over the impacts of effluent control costs in terms of the required price increase, potential

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*Note that the RCRA-ISS cost estimates used in this analysis also include baseline RCRA costs and, therefore, overstate the RCRA costs associated with solid wastes generated by effluent treatment. However, this analysis indicates no significant incremental impacts even with the overstated costs.

TABLE A-3

SUMMARY OF INCREMENTAL IMPACTS OF RCRA-ISS COSTS

Subcategory and Model Plant Size	Incremental Price Increase (percent)	Incremental Profitability Decline (percentage point)	(percent)	Incremental Capital Costs As Percent Of Fixed Investment
Chlorine-Diaphragm Cell				
Small	0.23	0.04	1.43	NA
Medium	0.07	0.02	0.31	0.02*
Large	0.06	0.01	0.10	NA
Chlorine-Mercury Cell				
Small	3.31	0.46	53.49	0.44
Medium	0.95	0.17	1.72	0.14
Large	0.59	0.11	0.79	0.09
Chrome Pigments				
Small	1.33	1.87	17.07	NA
Medium	0.52	1.22	5.92	NA
Large	0.67	1.01	3.93	NA
Very Large	0.43	0.66	1.48	NA

NA: Offsite waste disposal is assumed for these plants; therefore, no incremental capital costs are required for compliance with RCRA-ISS regulations.

* Only one of the six graphite anode diaphragm cell plants will incur incremental captial costs for compliance with RCRA-ISS requirements.

profitability decline, and capital requirements. The incremental impacts of RCRA-ISS costs are generally minimal.

The incremental impacts of RCRA-ISS costs are most significant for small chlorine mercury cell plants and chrome pigments plants. In the case of small chlorine mercury cell plants, the additional RCRA-ISS costs are not expected to result in plant closures because inelastic demand may allow complete pass-through of both effluent control and RCRA-ISS costs in final product prices.

In the case of chrome pigments plants, the same two plants (one small, one medium-sized) identified as possible production line closures due to effluent control costs alone would also be projected as closures due to the combined impacts of effluent control and RCRA-ISS costs. Additional closures are not anticipated due to the following reasons:

- Three small plants are exempt from BAT/PSES regulation. Without the effluent guidelines control equipment in place, they will produce no hazardous wastes attributable to BAT/PSES.
- The remaining small plant produces only chrome oxide green, a strong-selling product. In addition, this plant will face none of the OSHA costs which the producers of lead-containing pigments will incur.
- Of the two remaining medium-size plants, one is already in compliance with the regulations and one produces only chrome oxide green.
- Finally, the price and profitability impacts of the RCRA-ISS costs on larger plants is insignificant.

B. INDUSTRY OVERVIEW

This section briefly describes the chemical industry, the inorganic chemicals segment of the industry, and the economic relationships between chemicals and the general economy. The focus, which is emphasized in this section and applied throughout the report, is on the interrelated nature of the chemical industry and the rest of the U.S. economy. Virtually every sector of the economy, from heavy industry to small scale service operations, uses chemicals in some fashion. Many of these products which use chemicals are further manufactured to yield final goods for general consumption. Because of this, there may be any number of manufacturing steps involved between a chemical's manufacture and final consumption.

The purpose of this characterization is to determine and evaluate those factors which affect the economic condition of each of 10 inorganic chemicals. To do this, two types of economic variables are addressed: 1) the economics of production and those of the immediate end markets for the chemical, and 2) the final markets and the macroeconomic trends which affect them. Thus, each chemical is tied to those sectors of the economy where final consumption takes place. This provides a full picture of the direct and indirect determinants of demand, supply, and competition.

For each subcategory, the economic impact of pollution control regulations is determined. The core of this economic impact analysis is a comparison of the increase in costs due to control and the ability of the market to absorb these costs. This is only possible having evaluated all of the determinants of demand characterizing each subcategory.

The subcategory characterization for each chemical is presented in five sections: 1) Demand, 2) Supply, 3) Competition, 4) Economic Outlook, and 5) Characterization Summary.

B.1 DEMAND

The demand for all chemicals is reflected in diverse product paths which eventually lead to consumer products. The chemical industry can be divided into three groups based, in part, on these routes to the final market. Standard and Poors has developed a classification dividing the industry into 1) Chemical Products, 2) Synthetics, and 3) Basic Chemicals.

The first group, chemical products, includes final products such as paints, detergents, agricultural products, and pharmaceuticals. Demand for these chemicals flows directly from the end consumers to the chemical manufacturers. These products account for approximately 40 percent of the chemical industry's sales.

A second group of chemicals (accounting for 20 percent of sales), synthetics, is composed of man-made fibers, plastics, and synthetic rubber. This group is characterized by relatively high growth rates and profit margins although the fibers segment has experienced several bad years. These chemicals reach the ultimate consumer indirectly in products such as carpets, clothes, automobiles, and tires. As such, the demand experienced by chemical firms for acrylonitrile or nylon, for example, will depend on the demand at the end markets for acrylic or nylon fibers used in carpets and clothing.

The third group of chemicals (accounting for 40 percent of sales), called basic chemicals, includes "building block" chemicals, or intermediates, which are often used within the industry to make other chemicals. Most of the 10 chemicals of this study fall into this category. These chemicals are characterized by mature markets, that is, they have low growth rates and relatively stable demand. Chlorine is a good example of this type of chemical. It is widely produced at relatively slim profit margins and two-thirds of its production is used captively. Most producers manufacture chlorine in order to assure reliable supplies of this important intermediate. Other examples of intermediates and their uses include:

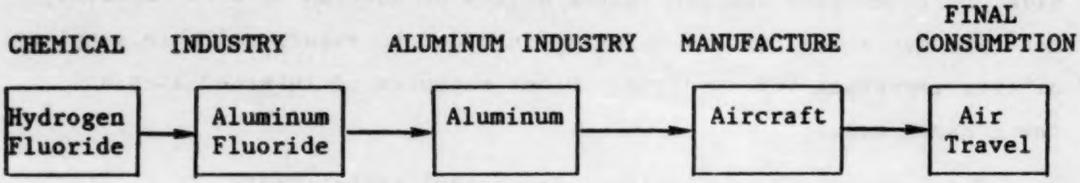
- Hydrogen cyanide as an input for methyl methacrylate
- Hydrofluoric acid as an input for fluorocarbons and aluminum fluoride
- Sodium dichromate as an input for chrome pigments and other chrome containing compounds.

Some of the 10 chemicals of this study are used directly by other industries. Included among these are:

- Aluminum fluoride which is used in the manufacture of aluminum
- Chrome pigments and titanium dioxide pigments which go into various paints
- Copper sulfate which is used in agricultural chemicals, in electroplating, and other industrial uses
- Nickel sulfate which is used in electroplating
- Sodium bisulfite which is used in photographic chemicals, in effluent treatment, and as a food preservative.

In characterizing the demand for the 10 chemicals of this study, the immediate markets and all of the downstream markets through final consumption must be accounted for. For example, reduced airfares in 1978 increased demand for air travel. Airlines, in turn, substantially increased their orders for aircraft. This increased the demand for aluminum, and thus aluminum fluoride and hydrogen fluoride (see Figure B-1). Although there were certainly other factors at work in these markets, the example does give a good indication of the potential complexity of demand for these chemicals.

FIGURE B-1



B.1.1 Demand Summary

Having evaluated all of the individual elements of demand and the economic forces at play, the total demand for each chemical is determined by synthesizing the individual markets. This is done by taking into account the portion of total demand represented by each submarket, the strength of each market, and any relationships which may exist among end markets. Finally, where applicable, a comparison is made between expected demand growth and the growth in the gross national product (GNP). In cases where the end markets for a chemical are very diversified and representative of the general economy, the chemical's total demand can be expected to grow with real GNP. Often, however, the end markets will be in faster growing markets (such as plastics) or slower growing markets (such as some metal plating operations) and the total demand growth will differ from that of GNP.

The individual end markets for these chemicals are useful in determining demand strength. To fully understand demand, however, one must also investigate the channels through which this demand flows, and the competition encountered in each market. Demand channels are discussed next, competition in a separate section.

B.1.2 Demand Channels

Channels of demand refers to the relationships between buyer and seller, including the extent and type of vertical integration, the type of contract, and the transportation of the product.

Vertical integration (forwards or backwards) is a measure of the degree to which one producer makes a series of chemicals in a continuous chain. Backward integration usually represents an attempt to obtain inputs more reliably and/or at lower prices. For example, aluminum companies have integrated backwards into aluminum fluoride and hydrogen fluoride production. Forward integration is a way of expanding a product line with guaranteed input chemicals. In either type of vertical integration, the result is captive production of a chemical. Captive production will affect an assessment of demand in several ways. Normally a chemical's production can be economically isolated so that price and profitability measures can be applied. With captive consumption, this may only be possible using confidential company data and a company-specific method for transfer prices.

The type of contract in use is another factor which further defines demand flows. There are many different types of purchasing arrangements ranging from no contract at all (i.e., purchases on the merchant market) to long-term contracts. From the purchaser's point of view, a long-term contract may be the next best thing to backward integration, offering sufficient security in price and availability. The other extreme for consumers is either short-term contracts or purchases on the spot market. This kind of arrangement may work best where there are many suppliers and the spot market is well developed. For example, some chlorine consumers make a portion of their needs, run their plants at high capacity utilization rates, and make spot purchases as necessary for the remainder of their needs.

A third factor which affects demand is transportation cost. The importance of these costs vary depending on the price of the chemical and the difficulty of shipment (e.g., dry vs liquid and inert vs hazardous). When a chemical has a relatively low unit value and is difficult to ship (such as chlorine), transportation costs can be significant enough to limit the market of a producer to the immediate region. Hydrogen cyanide is so poisonous that some firms are afraid to ship it and supply only captive requirements.

These three factors, which describe the channels through which demand flows, are considered in each subcategory and used to qualify the demand estimates where necessary.

B.2 SUPPLY

B.2.1 Production

The index of production for all U.S. manufacturing increased at an average three percent per year between 1967 and 1977. Chemical industry production grew at twice that rate, or six percent, for the same period. However, the inorganic chemicals segment, which includes many slow-growth chemicals, experienced an average production increase of only two percent per year.

TABLE B-1
CHEMICAL PRODUCTION

	Annual Change in Production 1967 - 1977
Total Manufacturing	3%
Chemicals and Products	6
Inorganic Chemical, n.e.c.	2
Alkalies and Chlorine	2

SOURCE: Chemical and Engineering News, "Facts and Figures," June, 1978.

The production of all chemicals tends to fluctuate with GNP though the swings in inorganic chemical production are less severe than those of organics. The 10 inorganic chemicals of this study are generally low-volume chemicals with production of less than 0.5 million tons per year. By comparison, the largest volume of chemical is sulfuric acid, with production of 34 million tons in 1977. Table B-2 illustrates several high volume chemicals. Two of the chemicals studied in this report rank among the 50 highest volume chemicals. Also illustrated are five chemicals which are related to some of the 10 chemicals of this report. Acrylonitrile is co-produced with hydrogen cyanide. Ethylene dichloride, vinyl chloride, and propylene oxide are end markets for chlorine. Several interesting characteristics are indicated by the data:

- The highest volume chemicals show less variability than others. They fell less in the 1975 recession, recovered less in 1976, and have lower overall growth rates.
- Most chemicals had big production drops in the 1975 recession with full recoveries in 1976. With some of the more volatile chemicals like vinyl chloride, the changes were very large (more than 20 percent).
- Chlorine and sodium hydroxide are co-produced and have very close production volumes. Demand for the two products, however, is not always equal, causing problems for manufacturers in balancing production for two products simultaneously.
- Growth rates have slowed for most chemicals in comparing the latest five years with the latest 10 years.

In addition to chlorine and caustic soda, titanium dioxide is also a rather high-volume chemical with production of 0.68 million tons in 1977. Titanium dioxide producers are faced with the dual problems of high variability in demand and a very low growth rate.

B.2.2 Producers

The 10 chemicals of this study are typically produced by different sized chemical companies. In addition, oil companies have been expanding into the chemical field for several years and some of these chemicals are produced predominantly by petroleum firms. Non-chemical companies also are involved in these chemicals. This usually represents backward integration on their part. For example, Alcoa aluminum company makes aluminum fluoride and hydrogen fluoride as inputs for aluminum manufacture. The sales of these chemicals usually represent less than five percent of corporate sales (typically around one percent).

Captive production is another important characteristic of these chemicals. Some of the chemicals are produced at large complexes, frequently as one of the preliminary chemicals in a product line. In this case, the economic strength of a chemical is very much interrelated with that of the other products.

B.2.3 Process

The process used to manufacture a chemical is of great importance, both environmentally and economically. As inputs to a process become more expensive or as pollution control requirements make a process more costly, manufacturers have an increasing incentive to find cheaper or "cleaner" processes. These forces have been acting on producers and many processes have changed. To lower costs, producers direct their efforts towards the most expensive elements of production. These include inputs such as energy, ores, and process chemicals.

The rising cost of energy is one of the greatest concerns of the chemical industry, which uses about 30 percent of U.S. total industrial energy. Of this "energy," 41 percent is used directly for feedstocks. The inorganic chemicals use fewer of these energy sources as feedstocks than other chemicals but are nonetheless very dependent on energy costs. Chlorine production, for example, uses tremendous amounts of electricity. Hydrogen cyanide uses natural gas for a feedstock. Hydrogen fluoride and titanium dioxide production use a great deal of process heat.

TABLE B-2

HIGH VOLUME CHEMICALS

Chemical	1977 Production (10^6 tons)	1976 Rank	Average Annual Change (%) 1976-77	1972-77	1967-72
Sulfuric Acid (top volume chemical)	34.3	1	2.7	2.0	1.8
Sodium Hydroxide (co-product with chlorine)	10.9	7	4	1.3	2.6
*Chlorine	10.1	8	1.9	1.4	3.2
Ethylene Dichloride (chlorine end market)	5.2	15	30.3	6.1	10.2
Vinyl Chloride (chlorine end market)	2.9	23	2.3	2.7	9.1
Propylene oxide (chlorine end market)	.95	41	4.0	4.5	8.8
Acrylonitrile (co-product with HCN)	0.82	44	8.2	8.1	9.4
*Titanium Dioxide	.68	49	-4.8	-0.4	1.4

* Studied in this report.

Source: Chemical and Engineering News, "Facts and Figures," June 1978.

The cost of ores is a second factor in the determination of processes. Titanium dioxide, for example, has two processes (chlorine and sulfate) and two ores (rutile and ilmenite). The rutile ore is purer (resulting in less process waste), more expensive, and in short supply. Because of this, efforts have been made to upgrate ores and to make the chloride process adaptable to lower-quality ores. Copper sulfate can be made from ore (as a byproduct of copper production) or from scrap. In all of these cases, the relative prices of the inputs will shape process decisions.

A third factor affecting process is the cost of process chemicals. Many chemical prices have recently risen by 15 or more percent per year. The price of sulfuric acid, a widely used chemical, increased 18 percent per year between 1972 and 1978.

Process changes in general are directed towards a higher quality product and/or lower production costs within constraints. These constraints include pollution control, capital rationing, and the market strength of the chemical. Pollution control may make some processes prohibitively expensive. Capital rationing and market strength are related in that insufficient demand may force a shutdown decision rather than a shift in process (even though a process may be more efficient, capital costs could be prohibitive). Producers will invest first in those areas where long-run profits look best (i.e., strong demand and reasonable costs).

B.3 COMPETITION

Having determined the end uses for a chemical, the demand within each end use, the channels through which these demands will be met, and the suppliers, we then turn to the competition in each market. This includes an analysis of three areas:

1. competitors selling the same product
2. substitution of other products
3. the market power of the sellers versus the buyers

The most obvious competition takes place within a subcategory among all of the producers of the product. The basic objective is to meet the demands of the buyer (e.g., quality, service, quantity, timing, location) at the lowest price. This seemingly simple process is complicated in the chemical industry by several factors:

- Captive production: Some of these chemicals are produced predominantly for use within a company as with chlorine. This can make the remaining non-captive production more competitive as purchasers have more of a buffer and actually compete with the sellers.

- Foreign competition: Foreign competition can effectively put a ceiling on the domestic price of a chemical. This is only true for a few of these 10 chemicals which have high enough prices to justify international shipping. The effect is reduced within the U.S. as the distance increases from major coastal ports.

- Economics of each process: Within many subcategories there are significant differences in the cost of production due to types of process, age, and size of the plant, capacity utilization, availability of inputs, and many other factors.

- Distance to markets: The lower value chemicals of this study are quite limited in their economical shipping distance. Thus, a producer can compete by being closer to his markets if shipping costs are significant.

- Product differentiation: Although these chemicals are generally "commodities," there are differences in the form (e.g., liquid versus dry), shipment size, and sometimes the additives in these chemicals. Titanium dioxide, for example, has two basic forms, several types of finishes, and can be shipped in a dry or slurry form.

- Discounting: Some companies post list prices and sell their chemicals at various discounts. Even within the industry, competitors may not know each other's real prices.

Competition through substitution by other products can occur at any point along the path of a chemical between production and final consumption. When chemicals are sold directly to end markets (as with paints, detergents, and fertilizers) there is one possibility for substitution. Titanium dioxide, which is used directly in paints, faces potential substitution from paint extenders and surfaces which do not use paint. When chemicals trace complex paths to final consumption, there are usually several opportunities for substitutions. For example, chlorine is used to make polyvinyl chloride which is used in pipes. Substitutes along this line of products include metal pipes and plastic pipes not using PVC.

The relative market power of sellers and buyers can have a major impact on the competitive stature of a chemical market. Generally, there is some balance of power between sellers and buyers but the extreme cases are useful for illustrative purposes. One extreme is that of a seller's market in which the demand for the product is strong and the buyers are price takers. Typically this type of market will have one or only a few sellers and many buyers. The other extreme is a buyers market in which many sellers must compete actively for a limited market.

The chemical industry and its end markets are generally quite competitive with few extremes of sellers or buyers markets. The 10 inorganic chemicals of this study are similarly competitive. The aluminum fluoride and hydrogen fluoride markets are buyers markets in that the aluminum companies captively supply most of their needs and purchase the remainder from chemical firms. Generally, however, the market power of buyers and sellers in these chemicals is determined by the forces of the marketplace.

B.4 ECONOMIC OUTLOOK

Any characterization of an industry is necessarily based on historical data. The impact of pollution control regulations, however, may occur several years hence. Because of this potential incongruity, this categorization includes an analysis of the major forces shaping the future of the chemical. This analysis is divided into three parts: 1) revenue;

2) manufacturing costs; and 3) profit margins. The implications of this flow is that revenues must increase at least as fast as manufacturing costs in order to maintain profit margins. Revenues are divided into quantity and price. The quantity outlook discusses the factors affecting demand volume and estimates future growth. The price section discusses the likelihood that demand will be adequate to allow price increases. The manufacturing cost section separates the major cost components and estimates a likely rate of increase in total manufacturing costs. Finally, the profit margin section estimates the likely outcome resulting from revenue and cost increases.

B.5 CHARACTERIZATION SUMMARY

The predominant features in the chemical industry in 1977 and 1978 are overcapacity and rising costs. The overcapacity results from the 1973-76 period in which capital spending increased 150 percent (see Table B-3). The spending has slowed but capacity has still been growing.

TABLE B-3

CAPITAL SPENDING BY 20 MAJOR CHEMICAL FIRMS

	millions of	% Change from Year
1971	2,516	5
1972	2,416	4
1973	3,031	25
1974	4,873	61
1975	5,661	16
1976	6,125	8
1977	6,144*	0.3

* Planned capital spending in current dollars for 20 firms.

SOURCE: Chemical and Engineering News, "Facts and Figures," June 6, 1977.

In general, markets have not expanded as quickly as capacity. In 1977, producers added 10 percent to U.S. capacity and will add another eight percent in 1978. However, capacity utilization is less than 80 percent now and markets have been expanding at only three percent.

In addition to low capacity utilization, manufacturing costs have risen precipitously. Raw material costs, which rose a total of 15 percent during 1976 and 1977, are expected to rise seven percent in 1978. Wage rates are expected to rise by eight percent and the cost of fuels and electricity by 12 percent.

The result of the overcapacity and rising costs will be tougher competition. Because of low revenues, producers will want to raise sales through price and/or volume increases. Price increases are less likely to be accepted in times of overcapacity because all producers are interested in capturing greater market share to increase volume. The conditions in the 10 inorganic chemical subcategories vary, but the conditions of overcapacity and cost increases are being felt in most subcategories.

C. METHODOLOGY USED IN ECONOMIC IMPACT ANALYSIS

1. INTRODUCTION

The purpose of this study is to determine the immediate economic effects of effluent control costs on ten chemical subcategories. In addition, the impacts of combined effluent and hazardous waste control costs (required for compliance with the Resource Conservation and Recovery Act's Interim Status Standards, i.e. RCRA-ISS) are determined for the subcategories of the inorganic chemicals industry that will incur both sets of compliance costs. The approach emphasizes the microeconomic impacts on each subcategory. The secondary, economy-wide impacts are given less consideration.

2. AREAS OF STUDY

The analyses of the economic impact of potential effluent guidelines on the subcategories address nine general issues. These issues were chosen by the EPA as indicative of the effects which regulations might have in a wide variety of situations. In dealing with the chemical industry, some will be more important than others. The nine areas of study are:

1. Price
2. Profitability
3. Growth
4. Capital
5. Number of plants
6. Production
7. Changes in employment
8. Community effects
9. Other

Although each of these issues is individually important, the interrelationships and the combined effects in all of these areas indicate the total impacts of the effluent guidelines. In particular, the price and profitability impacts largely determine the impacts in the other areas.

A number of questions can be asked in each impact area:

1. Price: What portion of the product price will go towards pollution control? Will producers be able to pass costs on completely or will margins be reduced?

2. Profitability: What will happen to total revenues, total costs and profits? What secondary effects will a profitability change have?

3. Growth: Will capacity growth rates change? What will happen to rates of modernization? Will there be plant closures? Will pretreatment regulations stimulate direct discharging? Will present customers convert to substitutes or reduce demand?

4. Capital raising ability: Will pollution control expenditures affect a company's capital raising capabilities?

5. Number of plants: Will regulations reduce the number of plants in a subcategory?

6. Production: Will there be curtailments? Will product lines be affected? What will be the long run effects?

7. Employment: Will there be employment reductions?

8. Communities: What will be the location of any cutbacks or curtailments? Will dislocated employees be absorbed by the local workforce? What secondary effects might occur?

9. Other: What other effects might there be? e.g., Balance of Payments, foreign investment in U.S. companies.

In this report, price and profitability impacts form the core of the analysis. All other impacts are derived from these two areas.

3. IMPACT METHODOLOGY

3.1 General Approach

The economic impact assessment is based on qualitative and quantitative analyses of each of the subcategories in the inorganic chemicals industry.

The qualitative side of the assessment consists of a detailed economic characterization of each subcategory. The characterization is intended to develop a detailed picture of industry trends in such areas as sales, profitability, competition, and product price. This characterization is used to depict a subcategory's current economic condition and its prospects for the future. This provides the essential background for estimating the economic impact of pollution control costs.

The quantitative side of the impact assessment consists of a "model plant" analysis. An economic or engineering model is a simplified representation of reality. Since there are too many plants in the inorganic chemicals industry to study the economic impact of pollution control costs individually on each one, models were used to represent the real plants in the industry. For example, the chrome pigments subcategory consists of 12 real plants which are represented in this study by four model plants. One model is designed to be typical of the five small plants in the subcategory, another of the three medium sized plants, and so on through the large and extra-large plants.

These models in effect act as surrogates in the analysis for the real plants they represent. The models are used in two respects:

- As engineering models, to estimate the cost of compliance with effluent regulations and, where applicable, RCRA-ISS requirements
- As financial models used to estimate how compliance with effluent control costs and, where applicable, RCRA-ISS costs will affect the product selling price and profitability of the real plants in the industry.

In the final step of the impact assessment the quantitative and qualitative analyses are brought together. Essentially, the industry characterization provides the background needed to evaluate the significance of the price and profitability changes. An important contribution of the characterization is in estimating the price elasticity of demand an industry subcategory faces (i.e., how responsive demand is to changes in price). If demand is inelastic (unresponsive), then even relatively large price increase estimates for a model plant would be considered relatively unimportant. However, the same level of model plant price increases combined with elastic demand — that is, demand which would fall off sharply with an increase in price -- would indicate potentially severe financial problems for the real plants represented by a model.

The following discussion will describe the elements of the methodology in detail. The discussion is divided into the following sections:

- Costs of Pollution Control
- Model Plant Analysis
- Determination of Industry Impacts

The first section describes the estimates developed by a technical contractor for effluent control costs and, where applicable, the costs of compliance with RCRA-ISS regulations. The second section describes the model plant analysis including 1) calculation of the maximum price rise and profitability decline that could result from pollution control costs; 2) a subjective estimate of price elasticity of demand based on the subcategory characterization; and 3) a screening analysis, based on these measures, designed to pinpoint model plants which may suffer particularly high impacts and require futher study. In the final section, the assessment of probable industry impacts (based on the model plant analysis and market and industry information developed in the characterization section) is discussed.

These sections are discussed in more detail below. Much of the detailed discussion of the financial assumptions and tools has been provided in appendices in order to present the methodology more clearly and concisely.

3.2 Costs of Pollution Control

3.2.1 Model Plant Parameters

Since, as noted above, it was impractical to examine every plant in an industry, the pollution control costs were estimated for "model plants" which represent the real plants in each subcategory. Some of the key variables used to specify model plants include process type, production capacity, flow rates, and pollutant loads. The appropriate number of model plants for each subcategory depends on the variability in these characteristics and the number of plants in the subcategory.

The model plants used in the analysis were specified by the technical contractor (Jacobs Engineering Inc.). Model plants for each of the subcategories were designed on the basis of annual production levels, with the number of sizes and production levels selected to correspond to the actual range of plants in each subcategory. Model plant financial parameters were developed by EEA and an economic subcontractor.

3.2.2 Effluent Control Costs

For each of the model plants, effluent control cost estimates were developed by the technical contractor. In this report, the cost estimates represent the costs required for direct dischargers to comply with best available technology economically achievable (BAT) limitations and for indirect dischargers to comply with pretreatment standards for existing sources (PSES).

3.2.3. Hazardous Waste Control Costs

Ten subcategories of the inorganic chemicals industry are included in this report. However, these ten subcategories actually cover 13 chemical manufacturing processes. For example, the chlorine subcategory covers two processes -- mercury, and diaphragm cell. Likewise, the titanium dioxide subcategory includes the chloride, chloride-ilmenite, and sulfate processes. Of the 13 processes covered in the 10 subcategories, only three processes will incur RCRA-ISS costs:

- Chlorine - Mercury cell
- Chlorine - Diaphragm Cell (Graphite Anode)
- Chrome Pigments

Other EPA analyses have also included titanium dioxide and sodium dichromate as segments which will incur RCRA costs. However, these segments are excluded in this analysis because trivalent chromium, the dominant metal contaminant in both subcategories, is not a hazardous waste according to the most recent established criteria for toxicity. Hydrofluoric acid and aluminum fluoride production will not incur RCRA-ISS costs because the concentrations of toxic metals in these processes' solid waste are low due to the large amounts of calcium fluoride and calcium sulfate generated by the effluent treatment system. For all other subcategories, the dominant metal contaminants in the solid waste are not hazardous wastes according to EPA's most recent toxicity criteria.

RCRA-ISS costs were estimated for plants in the affected segments by Jacobs Engineering Inc. on the basis of EPA's Office of Analysis and Evaluation "Draft Final Guidance Document For RCRA-ISS Costs." The costs are based on regulations promulgated through May 1980 for Sections 3001, 3002, 3003, and 3004 of the Resource Conservation and Recovery Act. Note that the costs developed for this analysis overstate the RCRA-ISS costs associated with solid wastes generated by effluent treatment because the estimates also include baseline RCRA costs (i.e., those that would be incurred even in the absence of effluent limitations).

Either model plant cost estimates or plant-specific cost estimates were developed for each subcategory. For example, in a subcategory such as the chlorine mercury cell segment, which has 25 plants incurring costs, cost estimates were developed for three model plants to represent the entire subcategory. However, in the chlorine-diaphragm cell segment, only six plants will incur costs, thus permitting the development of plant-specific costs.

These cost estimates may not match the costs used in other EPA analyses for two reasons:

- RCRA-ISS regulations have been revised repeatedly. The cost estimates used in this analysis reflect RCRA-ISS requirements promulgated through May 1980. Cost estimates in other analyses may reflect RCRA-ISS regulations promulgated through earlier or later dates.
- Previous analyses have developed "worst case" cost estimates reflecting the costs of on-site waste disposal for the affected plants. Further analysis has shown EPA that some of these plants will be more likely to dispose of their wastes off-site at lower costs.

In accordance with the Guidance Document, Jacobs Engineering Inc. estimated RCRA-ISS costs on the basis of the activities required for compliance with the regulations. The compliance activities were divided into two categories -- technical and nontechnical. As a general rule, activities in the technical category are defined as those which directly affect the design and operation of a waste disposal facility. Under this nomenclature, for example, a runoff control system is a technical cost, while sampling or recordkeeping is not. For RCRA-ISS, the technical activities are:*

- Runoff collection and treatment or disposal for land treatment and landfills. These systems must be in place within 12 months after promulgation.
- Closure for landfills. It was assumed that wastes would be disposed in one cell for a one year period, after which the cell would be closed. Therefore, closure is an annual event.
- The management of wastes at off-site waste disposal facilities. (In this case, management fees are incurred annually.)

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* The following summary of applicable RCRA-ISS costs is taken from the "Draft Final Guidance for RCRA-ISS Costs," Office of Analysis and Evaluation, EPA, December 1980.

The activities in the nontechnical category were defined as those which had an indirect impact on facilities design and operation. Activities in this category included:

- **Administration -- These activities are complementary to recordkeeping and reporting and are often implicitly rather than explicitly specified in RCRA-ISS. Some activities, such as maintaining an operating log, are evident; while others, such as general administration, are not.**
- **Recordkeeping and Reporting -- These activities are explicitly required and involve maintaining a manifest system and preparing reports.**
- **Monitoring and Testing -- Activities include installing and maintaining a system of test wells, sampling and analysis of groundwater, and maintaining records and reports.**
- **Training -- Employees must be instructed and provided on-the-job training.**
- **Contingency Planning -- Activities include provision for security (usually a fence); emergency preparedness and prevention; and Contingency Plan and Emergency Procedures. The most significant activities include a provision for fencing, the preparation of a contingency plan, and the provision of safety equipment.**
- **Financial Requirements -- All facilities must demonstrate ability to provide for site closure. Disposal facilities where wastes remain after closure must demonstrate the ability to provide long term care. While several mechanisms will be available through which facilities can meet the financial requirements, this analysis assumes that plants establish a trust fund for closure and a trust fund for post-closure monitoring and maintenance.**

The RCRA-ISS control costs were divided into four categories, of which three are:

- **Annual Operating -- These are incurred each year the plant is in operation.**
- **Capital -- One-time capital expenses, such as for fences.**
- **Initial -- Other one-time expenses, such as for setting up the manifest system for tracking wastes. These are treated in the model as capitalized expenses.**

The fourth category, which is payments into the closure fund, requires special attention. Each plant must establish a fund to pay for the costs of closing its disposal facilities and post-closure maintenance. In this analysis, it is assumed that the trust fund will be built up over twenty years in accordance with the RCRA-ISS specifications for financial requirements.* Note that this is a conservative assumption; other less costly mechanisms (e.g., securing a surety bond or letter of credit) would also be available.

It is important to note that the closure fund payments made via the trust fund mechanism are not a tax-deductible expense. This greatly magnifies their impact on the plant. In fact, the cost impact is almost doubled.**

3.2.4 Estimation of Investment and Annualized Control Costs for the Subcategory

Pollution control investment costs for each subcategory are estimated on the basis of model plant pollution control investment costs (developed by the technical contractor) and actual plant sizes. In this analysis, the investment cost for each actual plant is taken as the pollution control investment cost for the closest corresponding model plant.

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* Federal Register, Volume 46, No. 7, January 12, 1981, Rules and Regulations page 2821.

** Consider the following simplified calculation for net income after taxes:

$$NIAT = (R - C)(1 - t)$$

where: NIAT = Net Income After Taxes
R = Revenue
C = Cost
t = Tax Rate

In this study, 1-t equals 0.53 (see Appendix A). By multiplying through, the equation can be rewritten as:

$$NIAT = 0.53R - 0.53C$$

But if the cost is not tax-deductible, as in the case of the closure fund, the equation becomes:

$$NIAT = 0.53R - C$$

Thus, the effect of the cost is almost doubled. Note that in calculating annualized RCRA-ISS costs, the annual closure fund payment is divided by (1-t), or 0.53, in order to reflect this effect.

Total annualized control costs for each subcategory are estimated on the basis of model plant control costs, developed by the technical contractor, and current industry production levels. Model plant annualized control costs are calculated on a per ton basis and include the following:

- Annual operating costs
- Annualized capital costs obtained by multiplying the pollution control investment by a capital recovery factor (see Appendix A)
- Where applicable, the non-tax deductible closure fund payment required for RCRA-ISS compliance.

Plant specific capacity information and the technical contractor's estimate of capacity utilization were used to determine the tons of actual production corresponding to each model plant size for each subcategory. Total estimated control costs for each subcategory were obtained by multiplying the per-ton control costs for each model size by the corresponding production in each size category.

3.3 Model Plant Analysis

This section describes the model plant analysis used to predict potential industry impacts. There are four indicators used to evaluate the impacts of pollution control costs for each subcategory.

- Price Rise Calculation
- Maximum Potential Profitability Decline
- Price Elasticity of Demand
- Capital Ratio

These indicators are discussed below.

3.3.1 Price Rise Calculation

The price rise analysis assumes that the chemical manufacturer can immediately pass through all costs of pollution control in higher prices.

It is assumed that the price can be raised by the full amount necessary without resulting in any decline in physical sales volume, i.e. that demand is completely inelastic. To fully recover all pollution control costs, the price increase must include both the annual operating costs plus an annualized portion of the initial capital investment. The annual operating costs are simply divided by the number of tons produced to obtain cost per ton. The capital costs are annualized using a capital recovery factor. In this analysis, the recovery factor used is 0.218 (i.e., 21.8 percent of the capital costs must be recovered each year). This implies that all of the capital costs will be recovered in about five years. The annualized capital costs are added to the annual operating costs to obtain total annual pollution control costs. These total costs are divided by sales to derive a product price increase. Appendix A describes the capital recovery factor and the price pass-through analysis.

3.3.2 Profitability Decline

The profitability analysis assumes that no price pass-through is possible, i.e. demand is infinitely elastic. Therefore, the manufacturer must absorb all pollution control costs in the form of reduced margins or increased losses. The first step is to determine the baseline profitability (that is, the profitability of the plant before pollution control costs are incurred) for each model plant. Then, the after control profitability is calculated and compared to the baseline profitability. The magnitude of the profitability decline is used in conjunction with the other impact indicators to evaluate the potential impacts. Two measures of profitability are calculated using a discounted cash flow model: return on investment (ROI) and internal rate of return (IRR).

3.3.2.1 Return on Investment

The return on investment (ROI) is defined as the yearly cash income divided by the total investment. This measure is similar to the ROI figure often quoted by the industry. The difference is that the industry commonly uses earnings after taxes (net earnings) divided by investment, whereas this ROI is cash earnings (net earnings plus depreciation) divided by investment. Since the difference in ROI before and after the pollution control expenditure is what is to be examined, the cash ROI serves as well as the traditional ROI.

The ROI change from year to year depends on the cash position of the firm (which will vary with depreciation schedules and changes in operating costs). The analysis relied on an examination of the decline in ROI during the fourth period. This year was chosen for three reasons:

- Since the pollution control costs are introduced in the second period, pollution control operating costs are included in the cash position that year.
- Both initial capital investment in plant and equipment and pollution control investment costs are still subject to depreciation expense in that period. (Both plant and equipment are straight line depreciated for 10 years and control equipment for five years.)
- Since the calculations are made in nominal dollars, the assumed inflation rate of 6% annually has not yet distorted the costs and revenues upon which the ROI calculation is based.

The reasons cited above would have justified the third, fifth, sixth, and seventh period as well. However, the cash flows in those periods were not significantly different from that in the fourth (inflation accounts for the only differences.)

3.3.2.2 Internal Rate of Return

While the return on investment is easily calculated and used, it does not capture the effects of the investment life or the cash flow timing. These factors are taken into account in the discounted cash flow model which yields the internal rate of return as the profitability measure. The internal rate of return is calculated for each model plant as follows:

- The cash flow position is calculated for each of 27 years in the assumed life of the plant. (Simply stated, cash flow per period is defined as after tax profits plus depreciation, less any capital costs incurred during the period.)
- Using the opportunity cost of capital (discount rate) each future cash flow to the present period is discounted. This step allows for the fact that $1 earned in the future is worth less than a dollar earned today.
- The discounted cash flows are added to yield the model plant's net present value (NPV).
- The discount factor is adjusted to yield a net present value of 0. This discount factor is the internal rate of return.*

For some of the model plants, the baseline internal rate of return or the return after control costs was negative. This is the result when the cash flows are such that there is no discount factor which can raise the net present value to 0 (e.g., when the cash flows in all periods are 0). Since the IRR is therefore indeterminate, nothing can be deduced from differences in IRR. In these cases, therefore, changes in the other profitability measure, return on investment, were used.

3.3.2.3 Sources of Uncertainty in the Profitability Analysis

Profitability is dependent upon price, cost, and capital investment. The calculation of baseline profitability is made using the best estimate of these financial parameters presented in the characterization section. However, these point estimates have a wide variance, especially the estimate of price. List price and average unit value may differ by as much as 30-40 percent from actual selling price. Therefore, if the calculated profitability is inconsistent with profitability estimates developed through conversations with industry sources, the point estimate of price is adjusted (within the range suggested by the price data). This is an important step in the analysis because baseline profitability is the critical starting point for examining the profitability decline. The component variables driving the profitability estimate need only be within a reasonable range surrounding the best estimate in order to gauge the profitability decline resulting from pollution control costs.

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* Appendix B discusses the assumptions and calculations used to derive the ROI and IRR. For a more thorough discussion of cash flow analysis, theory and uses, see Managerial Finance (Weston and Brigham; Dryden Press: Hinsdale, Illinois).

This profitability analysis is not intended to specify precisely the actual returns accruing to each subcategory. This would only be possible using detailed confidential industry data. For this analysis, manufacturing costs estimated by a subcontractor and EEA were used to calculate profitability. This is consistent with the intent of the analysis -- that is, to determine the change in profitability that occurs when pollution control costs are included in the cash flow stream.

3.3.3 Price Elasticity of Demand

Generally, neither of the extreme assumptions of completely inelastic or elastic demand will be appropriate. A firm will usually be able to pass through a portion of the increased production costs from pollution control. An estimate of the potential for cost pass-through is a key consideration in the impact analysis. Pass-through is dependent upon the magnitude of the price rise and the price elasticity of demand.

Price elasticity of demand (rigorously defined as the percentage change in the quantity purchased given a one percent change in product price) is a function of:

- The number, closeness, and relative cost of available substitutes
- "Importance" to the purchaser's budget
- The relevant time period (short vs. long run).

Because there are many problems with historical data, econometric estimates of price elasticity of demand were judged to be of limited value. Thus, the analysis relies on subjective estimates of price elasticity, based on market information developed in the characterization.

3.3.4 Capital Analysis

The impacts of pollution control can go beyond increased annual costs and the annualized portion of capital costs. Pollution control facilities themselves can pose a significant one time expense, especially for smaller manufacturers. To determine the relative size of pollution control capital costs, they are compared with the fixed investment in plant and equipment. This comparison is expressed as pollution control capital expenditures as a percentage of dollar fixed investment in place. Because the capital intensity of the ten subcategories varies, this measure will give a useful indication of the relative burden of a new capital expenditure.

Because capital construction costs have experienced large increases in the 1970's, the fixed investment will vary widely in plants of various ages. The difference in age will also affect the accumulated depreciation. (Depreciation in this analysis is calculated as 10 year straight line for plants and equipment and as five year straight line for pollution control facilities.)

The cost of land represents a significant portion of initial costs for many of the proposed technologies. In an accounting sense, its value is not depreciable. The land may have equal or greater value in the distant future but physical depletion of the land, as well as the heavily discounted present value of any residual sales value may reduce its value. In any case, the initial expense of the land must be recovered so it is considered part of the capital constraint.

3.3.5 Model Plant Closure Analysis

An important part of the economic impact analysis of pollution control costs on the industry is to identify potentially "high impact" plants and closure probabilities. The EPA considers the price increase, profitability decline, and price elasticity of demand useful in providing an initial indication of high shutdown probability.

For each subcategory and for each of the pollution control options, a table is presented that summarizes the price elasticity of demand, necessary product price rise, and maximum potential profitability decline. Under the EPA's closure criteria, a model plant is considered a possible closure candidate if the demand is elastic, the price increase is greater than one percent, and the resulting profitability decline (in the case of no pass-through) is greater than one percentage point or exceeds ten percent of the baseline (before control) profitability. Price increases of one percent or less are assumed to have little effect on consumers or producers since a product price may fluctuate by at least one percent due to granting of discounts to volume purchases and also due to short-term supply and demand surges and declines. A profitability decline of less than or equal to one percentage point is assumed to have an insignificant impact on a plant's decision to curtail production or shut down as long as the absolute decline does not exceed ten percent of the plant's baseline profitability. Determining both the absolute percentage point decline and the percentage decline relative to baseline profitability facilitates the identification of plants which may close as a result of the potential profitability declines. In this way, model plants that are potential closure candidates are screened for further detailed analysis. The "Industry Impacts" section discusses the likelihood of actual plant closures as well as secondary impacts on unemployment, the community, etc.

3.4 Determination of Industry Impacts

This section describes the determination of industry impacts based on the model plant results described above. The probable industry price rise, profitability decline, and resulting impacts are determined for all manufacturers in each subcategory.

3.4.1 Price and Profitability Impacts

The model plant analysis suggests the maximum plant price rise and profitability decline. The model plant calculations must be evaluated in light of market information (developed in the characterization section) to estimate 1) the extent to which the price is likely to increase, and 2) the actual industry profitability decline that will result. If a significant price increase is needed to maintain profitability, an evaluation of the probability of achieving that increase is important.

Pass-through is dependent upon a host of factors including industry competitiveness, available substitutes and product demand, with the relationships among these factors made more complex by the action of market variables over time.

Profitability impacts are examined wherever complete pass-through is not possible. The portion of pollution control costs not recovered by price increases must be absorbed by producers in the form of reduced margins or increased losses. The likelihood of price pass-through and resultant impact on plant profitability form the basis for projections of other impacts in each subcategory.

3.4.2 Plant-Specific Impacts

Once the closure criteria are applied to the model plants, the probability of closure for the corresponding actual plants is examined in detail based on plant-specific factors and actual market conditions. The detailed analysis evaluates the extent to which profitability will decline if immediate and complete price pass-through is not possible. Thus, the model plant analysis serves to identify potentially high impact plants (based on EPA's closure criteria); the plant closure projections are made only after detailed evaluation of actual plant and market conditions.

3.4.3 Other Impacts

The nine impact areas studied in this report are highly interrelated. As previously indicated, the price and profitability effects are the keystone of the analysis. Price (and pricing history) is a measure which summarizes a wide variety of economic variables. It reflects supply conditions such as manufacturing costs, shipping costs, variation in the costs of manufacture, and the number of producers. Price reflects demand conditions as it measures the value of a chemical as an input to other processes. It also reflects competitive factors such as the price and availability of substitutes, foreign competition, capacity utilization, growth rates, and the number of producers.

Profitability levels in an industry directly affect the number of producers in an industry. As profitability declines, plants may be forced to shut down until industry capacity is more in line with demand. Thus, the profitability decline analysis can be used to help determine the number, location, and type of plants in a subcategory that may close due to the regulation; the course of future growth in the subcategory, and the role of foreign competition. This, in turn, can provide indications of secondary impacts on the community, employment, and the balance of payments.

D. SUBCATEGORY ANALYSIS

1. ALUMINUM FLUORIDE

1.1 CHARACTERIZATION

(NOTE: As discussed below in Section 1.2, this industry subcategory incurs no compliance costs. The following characterization data is presented for informational purposes only.)

Aluminum fluoride is a small but essential input in primary aluminum production. Together with cryolite it forms a molten electrolyte used to reduce metallic aluminum from alumina. In the reduction process, alumina (aluminum oxide) is dissolved in this electrolytic bath, and an electrical current is passed through it. At the carbon anode, oxygen from the alumina joins with carbon forming carbon dioxide and freeing aluminum metal. Aluminum fluoride is also used to a minor extent as a metallurgical and ceramic flux for welding and glazing, and in secondary aluminum production for the removal of magnesium from molten scrap.

Over 90 percent of the aluminum fluoride (AlF_3) produced is consumed by one end use: the production of primary aluminum. Given this market structure, the profitability, growth, and current production technology in the aluminum industry largely determine demand for AlF_3. Accordingly, this characterization analyzes those facets of the aluminum industry which affect AlF_3.

1.1.1 Demand

Since aluminum fluoride's major industrial function is primary aluminum production, demand for AlF_3 is determined by conditions in the aluminum end market.

Demand for aluminum has risen in almost all of its end use markets since the setback suffered by the industry in 1975. In 1978 production was 9.6 billion pounds, and 1979 output is expected to exceed the record 1974 level of 9.8 billion pounds. Figure 1-1 illustrates aluminum fluoride's position in the aluminum production stream relative to its raw material inputs and ultimate end markets.

In order to depict the total demand for aluminum (and thus AlF_3), the conditions in the individual end markets are summarized below.

1.1.1.1 End Markets

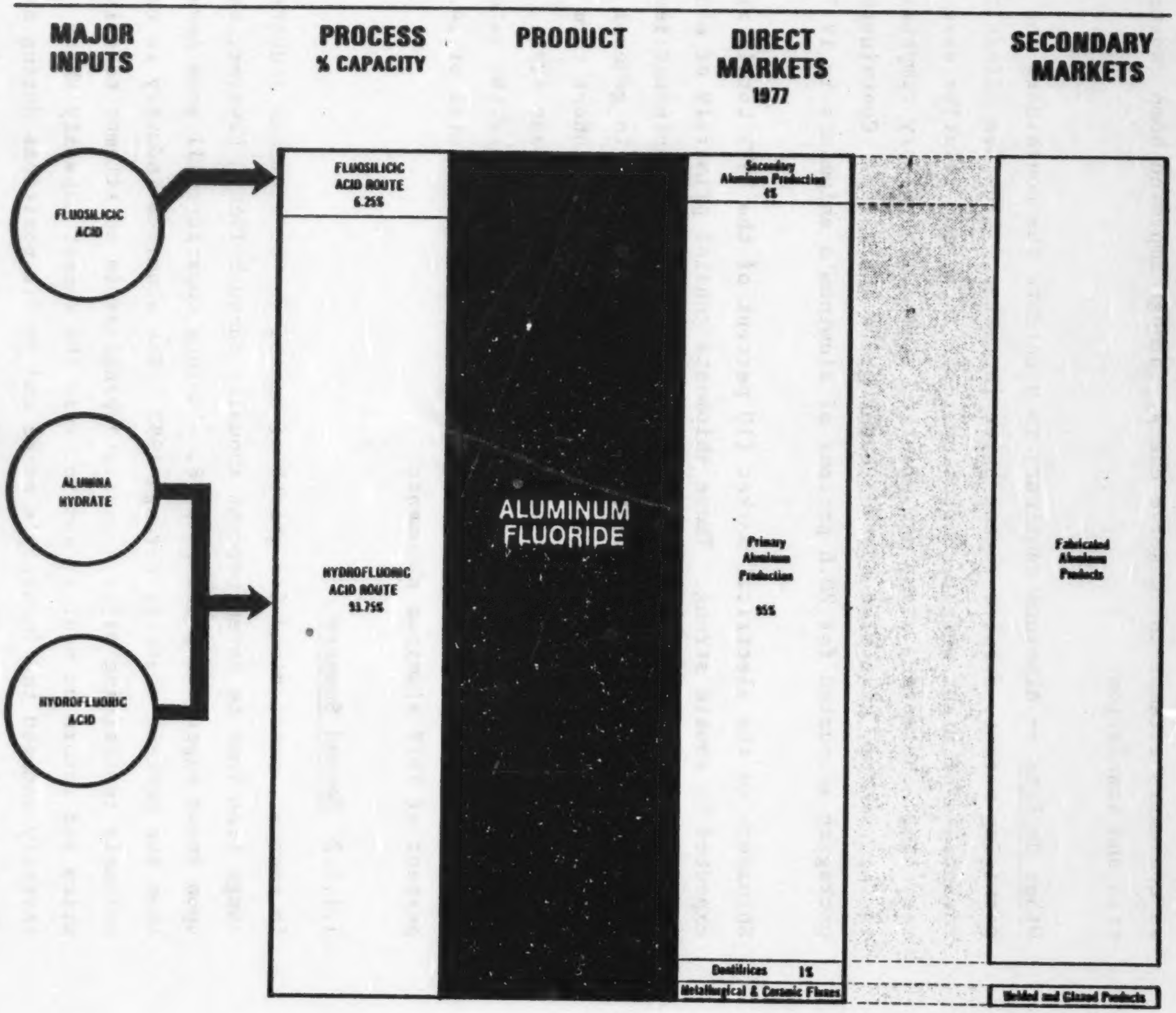
Transportation -- The transportation industries have led the resurgence in aluminum demand. In 1976, deliveries of aluminum to the transportation markets rose 44 percent and accounted for 19.3 percent of industry shipments. This increase reflects aluminum's increasing penetration of the automobile market. In an effort to improve gas mileage by lowering weight, automobile makers have incorporated an average of 114 pounds of lightweight aluminum in their 1978 models. This trend is expected to continue with estimates of aluminum usage per vehicle ranging from 150 to 200 pounds by 1980 and from 225 to 425 pounds by 1985.

Airline deregulation and the need to replace aging jet fleets have also increased aluminum consumption in the transportation sector. With passenger traffic and profits sharply higher, airlines are ordering new equipment at a record pace. Aluminum shipments to aircraft manufacturers have therefore increased substantially.

Building And Construction -- Building and construction constitute aluminum's largest end market, accounting for 23.1 percent of total 1977 shipments. Aluminum has penetrated the markets of both steel and wood in residential and industrial siding, doors, and windows. Due to their design these products can offer good insulating properties. Together

FIGURE 1-1

ALUMINUM FLUORIDE:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
FLUOSILICIC ACID
ALUMINA HYDRATE
HYDROFLUORIC ACID
FLUOSILICIC ACID ROUTE 6.25%
HYDROFLUORIC ACID ROUTE 93.75%
ALUMINUM FLUORIDE
Secondary Aluminum Production 4%
Primary Aluminum Production 95%
Dentifrices 1%
Metallurgical & Ceramic Fluxes
Fabricated Aluminum Products
Welded and Glazed Products

with foil backed fiberglass and foam insulation they should help strengthen aluminum's position in the building and construction market, as consumers attempt to conserve energy through improved home construction and insulation.

Other Markets -- Aluminum continues to penetrate the containers and packaging market, despite recent price increases. Aluminum offers the advantages of light weight, corrosion resistance, and relative ease of recycling. Moreover, steel and plastic, aluminum's primary competitors in this sector, have also posted recent price increases. Containers and packaging accounted for 20.8 percent of aluminum's shipments in 1977.

Shipments to the electrical market (10 percent of the 1977 total) are expected to remain strong. These shipments consist primarily of aluminum cable and towers. Shipments to the machinery and equipment sector, as well as to the consumer durables industries, are tied to general business conditions. Recessionary pressures may cause a short term decline in capital investment and consumer spending in these areas, but, in the long run, these markets should grow at approximately the rate of GNP growth. These two markets accounted for a combined total of 14.8 percent of 1977 aluminum shipments.

1.1.1.2 Demand Summary

In general, predictions for growth of demand in the aluminum industry range from four to seven percent annually through 1982. However, based upon known expansion plans in 1978, aluminum capacity will grow less than two percent annually through 1982. The aluminum industry is consciously restraining major capacity expansions in an attempt to drive up price and return on equity, and to avoid the excess capacity which severely damaged the industry's price and profit positions during demand downturns in 1970 and 1975. The difference between the rates of growth of demand and capacity should raise capacity utilization in the industry from the 92.5 percent of the first half of 1978 to approximately 95 percent and imports should increase their market share. Capacity utilization, however, is not expected to increase further. Production efficiency decreases beyond a capacity utilization of approximately 95 percent, because increased energy input is required per ton of aluminum. Increased natural gas and electricity prices will force industry to sacrifice output for efficiency. Thus, while aluminum demand will remain strong, growth in aluminum fluoride demand will be restrained by the industry's hesitance to expand capacity.

The outlook for AlF_3 is further clouded by technical developments in the areas of waste recovery and reduction technology. EPA standards on fluoride emissions have caused the industry to remove fluorides from air and water streams and from spent pot linings. These fluorides are then recycled and returned to the production process. Because aluminum fluoride is consumed only through mechanical and vapor losses, and not in the reduction reaction, these reclamation efforts can substantially reduce AlF_3 requirements. Industry sources estimate that up to 50 percent of consumed fluorides can be recovered through waste reclamation efforts.

The same sources differ regarding the remaining amount of fluoride recovery to be accomplished. Some sources indicate that as much as 25 percent of planned recovery equipment is not yet on line in the industry. Others maintain that virtually all economical fluoride recovery is currently being accomplished, and that further reductions will not occur without a substantial technological breakthrough. If further fluoride recovery is accomplished, slackening of aluminum fluoride demand may occur.

In addition to this possibility, there is a longer term threat to aluminum fluoride demand. Alcoa has developed a smelting process using a chloride instead of fluoride in reducing alumina. A 15,000 ton/year pilot facility in Anderson County, Texas has been in operation since 1976, and another 15,000 ton line has been added recently. Alcoa has plans to further expand this facility. The process is particularly attractive, as it has demonstrated electricity savings of 30 percent over the best Hall Cell technology and 44 percent over the industry average of 16,000 kilowatt hours per ton of aluminum. The process offers tremendous cost advantages, particularly at a time when the industry faces soaring electricity costs and difficulty securing the long-term power contracts essential for capacity expansion. The process is not yet commercially available due to technical difficulties. However, when perfected it will be licensed by Alcoa and made available to the entire industry.

Based upon the age of existing smelting facilities and the current status of the chloride technology, industry sources expect the Hall-Heroult process to remain the dominant production technology well into the 1990's. Until that time aluminum fluoride manufacture should remain a viable industry.

1.1.2 Supply

1.1.2.1 Production

As Table 1-1 illustrates, aluminum fluoride production has not grown substantially since 1968, despite a 39 percent increase in the production of primary aluminum. (See also Graph 1-1.) This is primarily due to fluoride recovery by aluminum producers. The large fluctuations in production during 1974 and 1975 reflect a period of rapid growth followed by contraction in the aluminum industry. Aluminum fluoride production should remain stable or decrease slightly over the next few years due to limited aluminum capacity expansions and continuing fluoride recovery efforts.

TABLE 1-1

PRODUCTION OF ALUMINUM FLUORIDE

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (dollars per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1968-77		0.7%		10.8%
1968	139.0	5.0	$193.50	
1969	143.1	2.9	197.00	1.8
1970	135.7	-5.2	199.00	1.0
1971	157.9	16.4	236.00	18.6
1972	138.0	-12.6	264.00	11.9
1973	140.2	1.6	164.00	0.0
1974	169.3	20.8	265.00	0.4
1975	129.4	-23.6	363.00	37.0
1976	142.2	9.9	454.00	25.1
1977	148.5	4.4	488.00	7.5

SOURCE: Department of Commerce.

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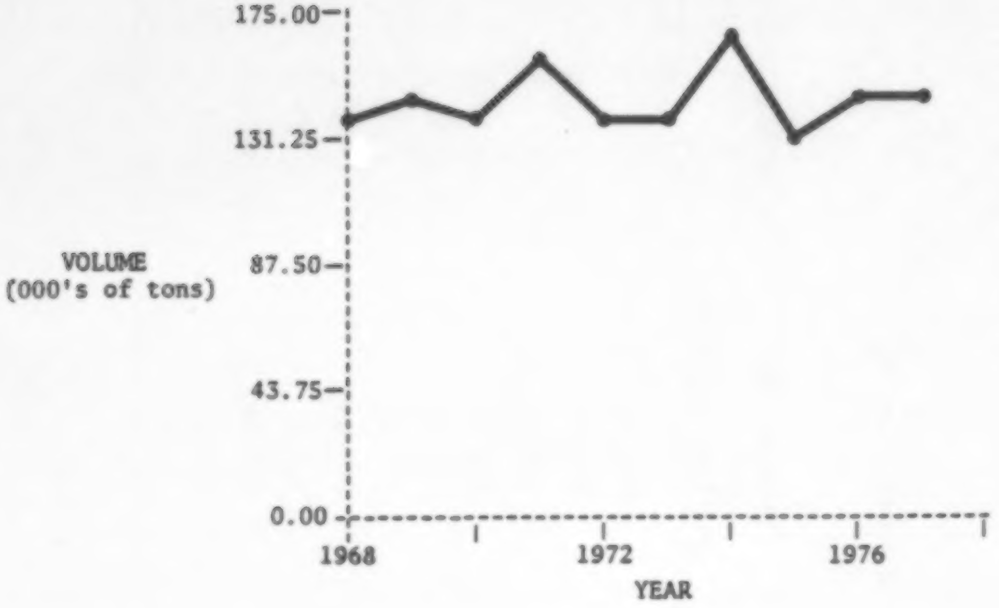
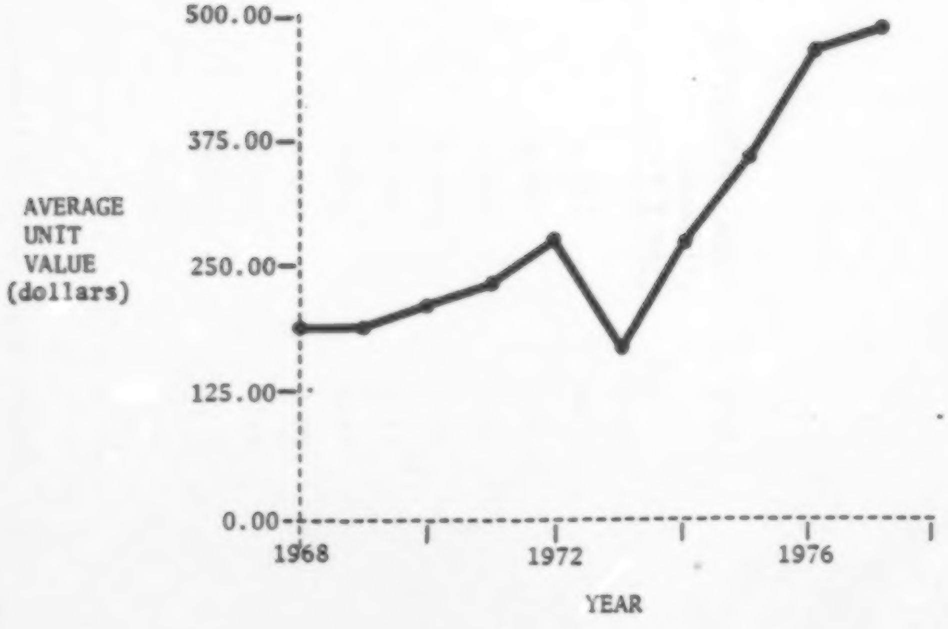
GRAPH 1-1
ALUMINUM FLUORIDE PRODUCTION AND PRICE





SOURCE: Department of Comm[illegible]

1.1.2.2 Producers

There are three bulk manufacturers of aluminum fluoride operating four plants. The two leaders, Alcoa and Kaiser, are integrated forward to aluminum, and account for 76 percent of total industry capacity. The third bulk producer is Allied Chemical Corporation, which sells its AlF_3 on the merchant market. In addition to these producers, the Ozark Mahoning Corporation produces a highly pure form of AlF_3 on a special order basis for use as an additive in dentifrices. Table 1-2 summarizes current producers and facilities.

Alcoa and Allied Chemical are completely integrated to the two major inputs, hydrofluoric acid and alumina hydrate. Kaiser has recently shut down its hydrofluoric acid facility, but maintains an internal source of alumina hydrate.

The supply situation for AlF_3 changed in late 1978 when the Stauffer Chemical Corporation closed its Greens Bayou, Texas facility, reducing domestic supply by approximately 10 percent. The facility, which was integrated with Stauffer's hydrofluoric acid unit at Greens Bayou was closed primarily due to the shrinkage of the HF market following EPA's and FDA's ban on fluorocarbons. Stauffer had previously supplied Union Carbide with hydrofluoric acid for fluorocarbon production until the latter closed its plant due to the regulation.

Two of the three leading aluminum producers, Alcoa and Kaiser, are producers of aluminum fluoride. The third, Reynolds Aluminum, is essentially integrated to AlF_3 except for the processing step. Reynolds provides acid grade fluorspar and alumina hydrate to Allied Chemical Corporation, which has a long-term contract to convert these raw materials to AlF_3 on a toll basis for use in Reynolds smelting facilities. All other aluminum manufacturers purchase AlF_3 on the merchant market from either Alcoa, Kaiser, or Allied.

TABLE 1-2

PRODUCERS OF ALUMINUM FLUORIDE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
Allied Chemical Corporation	Geismar, LA	35.0	24.1	Hydrogen Fluoride Aluminum Hydrate	
Aluminum Corporation of America (ALCOA)	Ft. Meade, FL Ft. Comfort, TX	10.0 50.0	41.4	Hydrogen Fluoride Aluminum Hydrate	Aluminum
Kaiser Aluminum & Chemical Corporation	Gramercy, LA	50.0	34.5	Aluminum Hydrate	Aluminum
Ozark & Mahoning Corporation (Subsidiary of Pennwalt Corp.)	Tulsa, OK	1[a]	NA	Hydrogen Fluoride[b]	

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a/ High purity grade produced on a special order basis only. Used in dentifrices.

b/ Supplied by Pennwalt.

SOURCE: Contractor estimates.

1.1.2.3 Process

Aluminum fluoride is produced by the reaction of hydrated alumina and hydrofluoric acid. Hydrated alumina is an intermediate obtained in the processing of bauxite ore to alumina. Hydrofluoric acid is produced by the reaction of the mineral fluorspar with sulfuric acid. The manufacture of aluminum is governed by the following reaction:

$$Al_2O_3 \cdot 3H_2O + 6HF \rightarrow 2AlF_3 + 6H_2 + 3O_2$$

The process generates no by-product waste materials. However, some process wastes are generated by gas scrubbers, leaks, and spills. Estimated material requirements and costs for AlF_3 production are found in Table 1-3.

AlF_3 can also be produced using fluosilicic acid as a starting material. Fluosilicic acid is a by-product of phosphoric acid manufacture. Currently Alcoa operates one plant in Fort Meade, Florida using this process.

It is anticipated, however, that the fluosilicic acid route will continue to constitute only a minor part of total aluminum fluoride production. Phosphoric acid manufacturers have a market for fluosilicic acid in water treatment, and seem unwilling to integrate aluminum fluoride production into their existing operations.

1.1.3 Competition

There are currently no commercial substitutes for aluminum fluoride in aluminum manufacturing. Alcoa's chloride process may offer competition when it becomes commercially available. However, the determining factor is expected to be potential electricity savings rather than price competition with aluminum fluoride because on a per unit of product basis electricity is a much more costly input than either electrolyte.

TABLE 1-3a

ESTIMATED COST OF MANUFACTURING ALUMINUM FLUORIDE*
(Mid-1978 Dollars)

Plant Capacity	25,400 tons/year
Annual Production	17,500 tons/year (69% capacity utilization)
Fixed Investment	$9.7 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Fluorspar (97%)	1.59 tons	73.33	116.60
- Sulfuric Acid (98%)	1.98 tons	39.98	79.20
- Alumina trihydrate	.935 tons	107.75	100.70
• Utilities			
- Electricity	130 kWh	.03	3.90
- Fuel	2.04 MMBtu	2.50	5.10
Total Variable Costs			$305.50
SEMI-VARIABLE COSTS			
• Labor			19.60
• Maintenance			27.60
Total Semi-Variable Costs			$ 47.20
FIXED COSTS			
• Plant Overhead			4.90
• Depreciation			55.20
• Taxes & Insurance			8.30
Total Fixed Costs			$ 68.40
TOTAL COST OF MANUFACTURE			$421.10

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 1-3b

ESTIMATED COST OF MANUFACTURING ALUMINUM FLUORIDE*
(Mid-1978 Dollars)

Plant Capacity	57,300 tons/year
Annual Production	39,500 tons/year (69% capacity utilization)
Fixed Investment	$15.8 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Fluorspar (97%)	1.59 tons	73.33	116.60
- Sulfuric Acid (98%)	1.98 tons	39.98	79.20
- Alumina trihydrate	.935 tons	107.75	100.70
• Utilities			
- Electricity	130 kWh	.03	3.90
- Fuel	2.04 MMBtu	2.50	5.10
Total Variable Costs			$305.50
SEMI-VARIABLE COSTS			
• Labor			10.90
• Maintenance			19.90
Total Semi-Variable Costs			$ 30.80
FIXED COSTS			
• Plant Overhead			2.70
• Depreciation			39.80
• Taxes & Insurance			6.00
Total Fixed Costs			$ 48.50
TOTAL COST OF MANUFACTURE			$384.80

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 1-3c

ESTIMATED COST OF MANUFACTURING ALUMINUM FLUORIDE*
(Mid-1978 Dollars)

Plant Capacity	73,900 tons/year
Annual Production	51,000 tons/year (69% capacity utilization)
Fixed Investment	$18.3 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Fluorspar (97%)	1.59 tons	73.33	116.60
- Sulfuric Acid (98%)	1.98 tons	39.98	79.20
- Alumina trihydrate	.935 tons	107.75	100.70
• Utilities			
- Electricity	130 kWh	.03	3.90
- Fuel	2.04 MMBtu	2.50	5.10
Total Variable Costs			$305.50
SEMI-VARIABLE COSTS			
• Labor			10.20
• Maintenance			18.00
Total Semi-Variable Costs			$ 28.20
FIXED COSTS			
• Plant Overhead			2.50
• Depreciation			36.00
• Taxes & Insurance			5.40
Total Fixed Costs			$ 43.90
TOTAL COST OF MANUFACTURE			$377.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

Aluminum fluoride is an essential but relatively low volume input in aluminum manufacturing, and therefore primary aluminum producers seek reliable supplies. Alcoa and Kaiser have achieved reliable supplies through backward integration, while other producers have established long-term contracts and firm supplier-customer relationships. According to industry sources, contractual arrangements range from one and two year agreements to long-term toll conversion contracts and changes of suppliers are rare. Thus, there is very little short-term competition between domestic producers in the AlF_3 market. Imported AlF_3 also offers little competition because in recent years ocean shipping rates have made it noncompetitive, particularly in a market with excess domestic capacity.

1.1.4 Economic Outlook

An industry's profitability is the difference between total revenues and total costs. There are factors that influence these independently so it is useful to present a revenue outlook and cost outlook separately.

1.1.4.1 Revenue

Total revenue is the product of the quantity sold and the average unit price. Though these two variables are discussed separately below, it should be recognized that they are interrelated.

1.1.4.1.1 Quantity

The quantity of aluminum fluoride produced and sold domestically should remain stable or decrease slightly through 1984, then grow at the rate of expansion of Hall cell reduction facilities into the 1990's. Wide scale commercialization of Alcoa's chloride reduction process will eventually eliminate AlF_3 use in aluminum processing, but this should not occur until the mid-1990's. Important factors which will influence demand for this commodity are the following:

- Strength of the aluminum market

- Lack of planned capacity expansion among primary aluminum producers
- Potential for further fluoride recovery by the aluminum industry
- Alcoa's development of energy conserving chloride reduction technology, which could ultimately eliminate need for AlF_3 in aluminum processing.

Thus, while there are some conflicting forces and trends, the aluminum fluoride industry appears to have matured and little future growth is expected.

1.1.4.1.2 Price

A great deal of the aluminum fluoride produced by both Alcoa and Kaiser is used captively. In this captive segment of the market the price of AlF_3 has little meaning. The profitability of the entire aluminum production stream is the relevant criterion for making production decisions, rather than the merchant market price.

Aluminum fluoride is an essential ingredient in primary aluminum production although a relatively insignificant input in terms of cost. It represents less than two percent of the current aluminum ingot price. With aluminum prices rising and demand strong, necessary price increases in AlF_3 could be sustained in the merchant market. This assessment is based on the following factors:

- Demand for AlF_3 is inelastic. Consumption cannot be curtailed without cutting primary aluminum production. This will not occur as long as it remains profitable.
- Three firms control the entire industry.
- There is little competition among producers, with the merchant market characterized by long-term, stable supplier-consumer relationships.

There seems to be, however, a chance of increasing competition in the future. There is currently excess capacity in the industry, with 1977 capacity exceeding consumption by 16 percent, or 27.9 thousand tons. The situation has improved somewhat with the closure of Stauffer's 16.5 thousand ton per year facility in Texas, but extensive fluoride recovery could again depress capacity utilization in the industry.

The downward pressure exerted by excess capacity on the prices of AlF_3 could be intensified by the current market structure. Alcoa and Kaiser, the two producers who are integrated downstream to aluminum, produce AlF_3 primarily to meet their own needs. Both, however, have excess capacity which they attempt to utilize by selling aluminum fluoride on a merchant basis.

If the excess production is sold at a price above the cost of the variable inputs, then utilizing this productive capacity lowers the unit cost of the aluminum fluoride they consume captively, as fixed costs are allocated among a greater number of units produced. Thus, there is an incentive for the integrated aluminum producers to keep the price low and capacity utilization high. If this situation develops, Allied must follow similar pricing policies to remain competitive. Thus, the possibility of increasing profit margins in an industry facing excess capacity and a demand downturn is substantially lowered. In fact, if demand declines, margins may shrink as producers compete more vigorously to maintain high capacity utilization.

1.1.4.2 Manufacturing Costs

Aluminum fluoride production requires two major inputs; hydrofluoric acid and alumina hydrate. The process for manufacturing HF is relatively energy intensive, and manufacturing costs will climb as energy prices rise.

Alumina hydrate is an intermediate obtained in the processing of bauxite to alumina, and thus its cost is a function of current bauxite prices. About 90 percent of all bauxite used by the domestic aluminum industry is imported from member countries of the International Bauxite Association (IBA). The IBA has been trying to agree on a common price formula, but to date has been unable to do so. However, the successful negotiation of a cartel pricing arrangment could raise the price of bauxite ore, and thus the cost of producing alumina hydrate.

The overall outlook is for the cost of manufacturing AlF_3 to increase at a moderate rate. The cost of the hydrofluoric acid input should increase fairly rapidly but total cost increases should be moderated somewhat by lower increases in bauxite costs.

1.1.4.3 Profit Margins

Much of the aluminum fluoride produced is used captively; as such, it has no "price" and therefore no profit margins.

In the merchant market, the price of aluminum fluoride is likely to remain low due to vigorous intra-industry competition for market share. This, coupled with rising manufacturing costs, is likely to keep profit margins on merchant AlF_3 fairly slim during the next few years.

1.1.5 Characterization Summary

Aluminum fluoride manufacture should remain a stable industry into the 1990's. As an essential ingredient in aluminum processing, AlF_3 will be produced as long as aluminum manufacture by the Hall process is profitable.

Growth, however, is not expected to be strong. The aluminum industry is restraining major capacity expansions to increase prices and return on equity, and thus market growth will be small. In addition, fluoride recovery technology will continue to reduce AlF_3 consumption per ton of aluminum produced.

In the long-term, Alcoa's chloride smelting process could potentially eliminate demand for AlF_3. However, due to the lifetime of current smelting facilities and the magnitude of the capital investment necessary to install the new process, it is not expected to have a major impact until the 1990's.

1.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the aluminum fluoride industry to comply with BAT effluent control standards. A survey by the technical contractor revealed that all five aluminum fluoride manufacturers are direct dischargers having BPT in place and operating. For this subcategory, BAT is equivalent to BPT. Since there will be no incremental costs above BPT required for compliance with BAT regulations, effluent regulations will have no impacts on the aluminum fluoride subcategory.

1.2.1 Pollution Control Technology and Costs

As noted above, no new pollution control costs will be incurred by the aluminum fluoride subcategory. The following detail on pollution control technology and costs is provided for informational purposes only.

Capital and operating cost estimates developed by the technical contractor for pollution control equipment designed to meet BPT effluent limitations (already in place and operating) are shown in Table 1-4. The process reaction for forming aluminum fluoride generates no by-product waste material. Wastewater flows, however, are generated by air pollution control scrubbers, leaks, spills and washdown.

The treatment process involves three steps to achieve BPT removal:

o Equalization: Wastewater streams are collected in an equalization tank.

- **Lime Precipitation:** Lime is added to raise the pH to six or seven. The wastewater is then transferred to a mixing tank where the pH is raised to ten. Fluorides are precipitated as calcium fluoride, and metals as metal hydroxides.
- **Settling:** Solids are settled in a lagoon, and the effluent overflow is discharged after final pH adjustment.

Pollution control cost estimates have been developed for three model plant production sizes: 17,500 tons per year (TPY), 39,500 TPY, and 51,000 TPY. These costs are summarized in Table 1-4.

TABLE 1-4: POLLUTION CONTROL COSTS

Chemical: Aluminum Fluoride

Model Plant Production (tons/year)	BPT		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
17,500	$400,919	$164,720	For this subcategory, BAT is the same as BPT. There are no incremental costs above BPT required for compliance with BAT regulations	
39,500	513,946	231,613		
51,000	600,683	266,612		

Source: Technical Contractor
Note: All costs are in mid-1978 dollars

2. CHLORINE

2.1 CHARACTERIZATION

Chlorine is a very large volume chemical with a great number of end uses in organic chemicals, inorganic chemicals and other industrial applications. Because it is a critical input for several processes, many producers make it for their own use; two-thirds of the chlorine is used captively. Because chlorine is a low value commodity, economical shipping distances are limited. Therefore, competition occurs on a regional basis and foreign trade is negligible.

Chlorine is manufactured through the electrolysis of salt using vast amounts of electricity. Sodium hydroxide is produced as a coproduct in approximately the same volume. Balancing the demand for these two products and coping with the rapidly rising cost of electricity are two of the major concerns of chlorine manufacturers.

2.1.1 Demand

Chlorine and sodium hydroxide (caustic soda) have a very wide variety of uses, none of which make up a predominant portion of total product demand. In 1977, end uses for chlorine were as shown in Figure 2-1. Because of this diversity of uses, demand for these chemicals is not overly dependent on fluctuations in any one market. In addition, since over 60 percent of chlorine production is captive, its internal use is subject to the demand fluctuations of the final products made by each producer, such as PVC and pulp and paper. Caustic demand, however, is dissimilar to chlorine in that its merchant sales represent 67 percent of production and only 33 percent is captive. Thus, many producers who produce chlorine based upon their needs for downstream chemicals may not produce the optimum amount of caustic (and vice versa). This problem is ameliorated somewhat by the large merchant market for caustic and relatively strong demand. Although this analysis concentrates on chlorine and its end markets, it should be kept in mind that manufacturers must continuously balance the demands of the two chemicals. In order to depict the total demand for chlorine, the conditions in the individual end markets are summarized below.

2.1.1.1 End Markets

Polyvinyl Chloride

Polyvinyl chloride (PVC) is chlorine's strongest market, accounting for approximately 17 percent of chlorine consumption. PVC is a plastic used in building and construction, electrical applications, household applications, and consumer goods. The market for PVC has grown rapidly (7.2 percent annually, 1971 through 1978) and is expected to continue growing. Some sources have predicted annual growth rates as high as 8 percent. The vinyl siding market may contribute significantly to this growth.

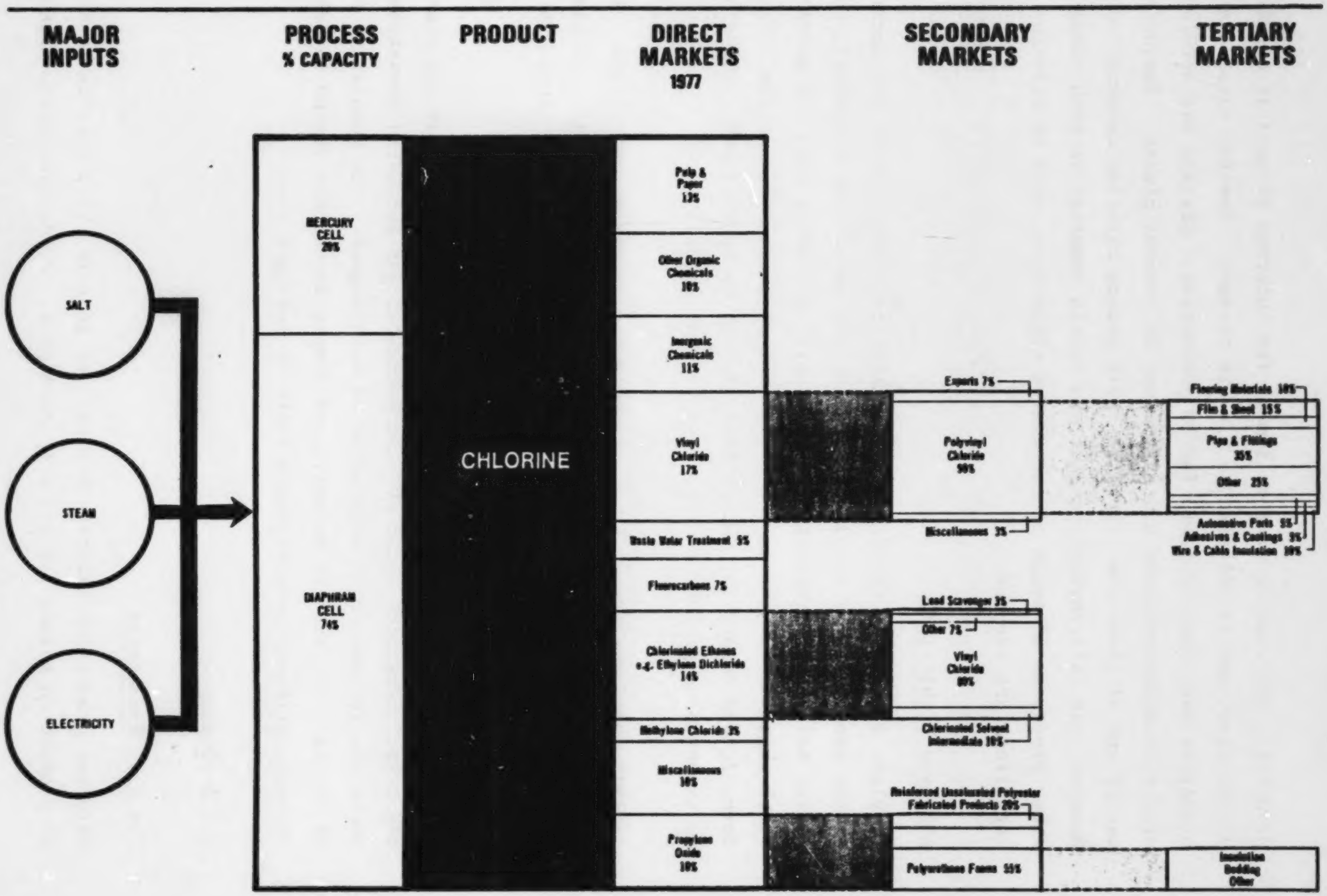
Although demand is strong, capacity utilization fell to 75 to 80 percent when Diamond Shamrock opened a 500,000 ton/year plant in 1978 (the average plant is half this size). Reduced capacity utilization has created weak prices. Several other producers are planning expansions which may contribute to continuing utilization and pricing problems for several years.

Propylene Oxide

Propylene oxide (PO) is used in the production of polyurethane foam products and unsaturated polyester fabricated products. These, in turn, go into automobiles, refrigerators, furniture, and textiles. Propylene oxide is produced by the chlorohydrin process, using chlorine, water,

FIGURE 2-1

CHLORINE:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
TERTIARY MARKETS
SALT
STEAM
ELECTRICITY
MERCURY CELL 26%
DIAPHRAM CELL 74%
CHLORINE
Pulp & Paper 13%
Other Organic Chemicals 10%
Inorganic Chemicals 11%
Vinyl Chloride 17%
Waste Water Treatment 5%
Fluorocarbons 7%
Chlorinated Ethanes e.g. Ethylene Dichloride 14%
Methylene Chloride 3%
Miscellaneous 10%
Propylene Oxide 10%
Exports 7%
Polyvinyl Chloride 90%
Miscellaneous 3%
Lead Scavenger 3%
Other 7%
Vinyl Chloride 80%
Chlorinated Solvent Intermediate 10%
Reinforced Unsaturated Polyester Fabricated Products 20%
Polyurethane Foams 55%
Flooring Materials 10%
Film & Sheet 15%
Pipe & Fittings 35%
Other 25%
Automotive Parts 5%
Adhesives & Coatings 5%
Wire & Cable Insulation 10%
Insulation
Bedding
Other

propylene, and caustic soda or lime. The chlorine is used as an oxidizing agent and is released as a waste product. Several alternate processes have been proposed for PO production. Oxirane has developed a direct oxidation process now being used in several plants. Increased use of any of these new processes could reduce chlorine consumption. However, the chlorohydrin process may remain competitive with these other processes if means of increasing efficiency, such as chlorine recycling, are adopted.

Ethylene Dichloride

Ethylene dichloride (EDC) is an intermediate chemical with end markets in the production of vinyl chloride (80 percent of EDC's market), chlorinated solvent intermediates (10 percent), and other uses (10 percent). Vinyl chloride is used in the production of polyvinyl chloride. Therefore, future demand for EDC is tied closely to that of PVC. EDC demand is expected to grow by four to five percent annually.

In 1978, the question of EDC's carcinogenic potential was raised. Vinyl chloride producers had similar problems a few years earlier. Although most EDC is consumed captively, there is a potential for costly EPA or OSHA regulation.

Ethylene dichloride and vinyl chloride are good examples of chlorine's end uses. They also point out the potential for increased downstream costs due to government regulation of carcinogens. The cumulative effects of regulations have the potential to dampen downstream demand for chlorine through increased manufacturing costs or outright bans.

2.1.2 Supply

2.1.2.1 Production

Chlorine production reached 10.6 million tons in 1977, placing it eighth in production volume for all U.S. chemicals. Production volume grew at a strong and steady rate throughout the 1950's and 1960's; annual increases of 10 percent were not uncommon. In the 1970's, two recessions caused temporary drops in volume. However, the long-term growth trend appears to have been reduced significantly also. The average annual growth rate between 1970 and 1977 was 1.1 percent. In the next five years, demand is expected to keep pace with the GNP. Rapid growth in some end markets, such as plastics, could cause chlorine demand to outpace GNP by one or two percentage points. Table 2-1 and Graph 2-1 show production and average price data for 1968 to 1977.

2.1.2.2 Producers

Chlorine is produced by more than 30 companies; six producers account for over 70 percent of the total industry capacity. Dow Chemical is the largest, with 30 percent of the capacity (see Table 2-2).* This industry concentration statistic can be misleading, however, because some manufacturers (not necessarily the largest) specialize in merchant markets, whereas others (including some large producers) produce primarily for captive consumption. Olin, PPG, and Diamond Shamrock are the largest merchant producers.

Most chlorine (over 60 percent) is produced for captive use. In chemical companies, downstream products include a wide variety of chlorinated inorganic and organic compounds. Nonchemical companies generally use chlorine and caustic more directly, e.g., for bleaching pulp and paper; included in the list of manufacturers are several pulp and paper and aluminum companies. Backward integration by all of these companies allows them to control the cost and availability of critical raw materials. A captive producer can lower costs by running his plants at a high capacity utilization rate. (In general, there is less captive use of caustic soda, so a large and predominantly captive producer of chlorine may be a major supplier of caustic.)

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*Note that only chlorine plants using mercury or diaphragm cells will be covered by effluent regulations.

Productive capacity has grown faster than demand for several years. Although several plants have shut down since 1975, capacity additions have exceeded shutdowns. Further expansions have been planned for the 1980's, even though capacity utilization has dropped.

2.1.2.3 Processes

About 94 percent of all U.S. chlorine is produced by the electrolysis of salt. The coproduct, caustic soda (sodium hydroxide), is produced in nearly the same volume (ratio of 1:1.13).

Production is governed by the following reaction:

$$2\ NaCl + 2\ H_2O \xrightarrow{\text{direct current}} Cl_2 + 2\ NaOH + H_2$$

The two major manufacturing methods use either mercury cells (20 percent of the capacity) or diaphragm cells (74 percent of the capacity). The trend away from mercury cells is increasing; there have been no new mercury cells built in the U.S. since 1970. Manufacturing costs were estimated for three model plants for each process. Table 2-3 presents cost estimates for mercury cell plants and Table 2-4 presents cost estimates for diaphragm cell plants.

The two electrolytic processes have many similar characteristics. Regardless of the process, the brine solution needs to be purified. Several manufacturers obtain their brine from nearby salt domes through steam injection. The brine is purified and then sprayed into the electrolytic cells. A typical chlorine plant has rows of cell lines. Thus, capacity is somewhat flexible. Older electrolytic plants produced from 65 to 475 metric tons of chlorine per day; newer plants generate 725 to 900 metric tons per day. Some plants and expansions under construction will yield 1000 or more metric tons per day.

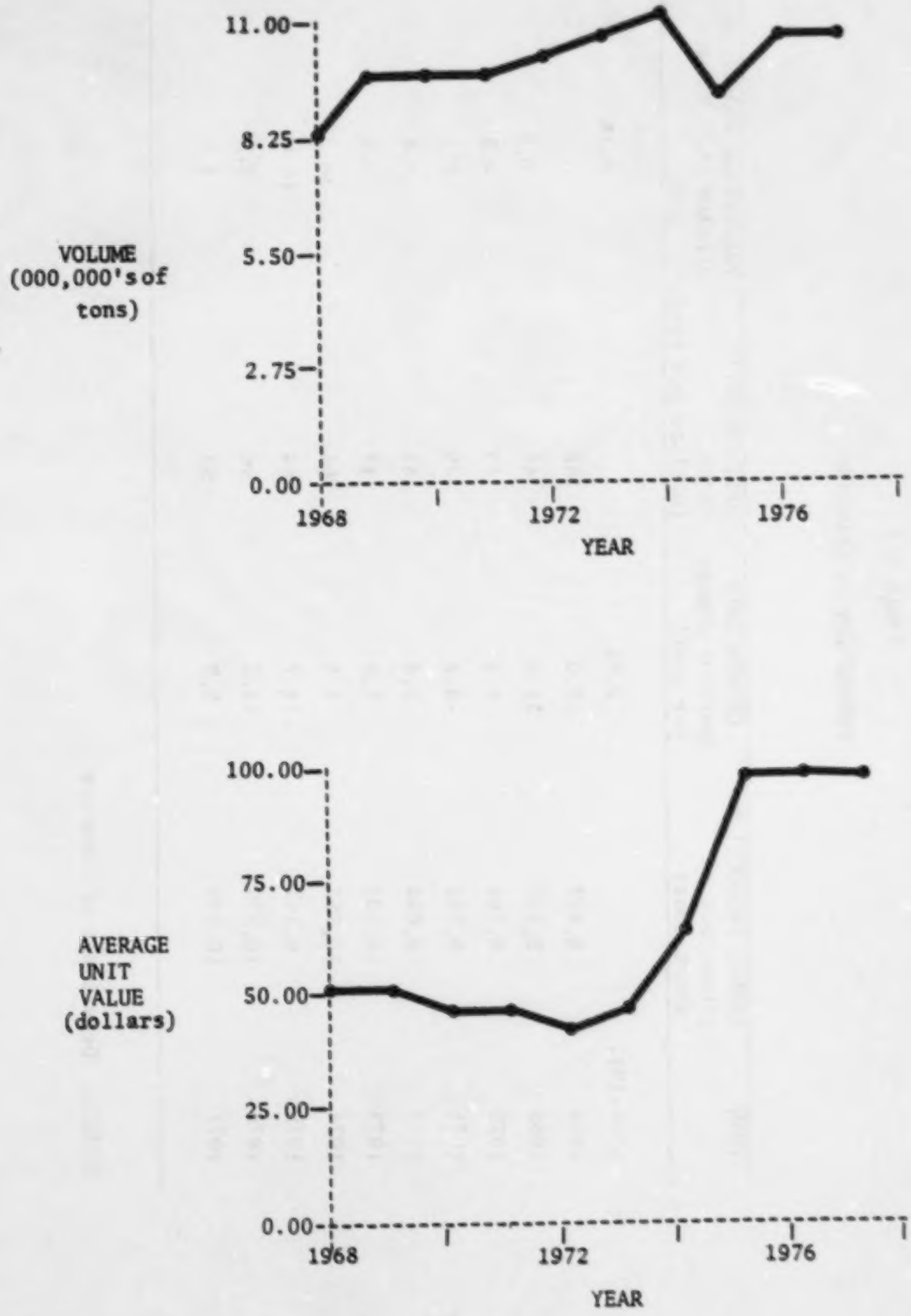
TABLE 2-1

PRODUCTION OF CHLORINE

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (dollars per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1968-1977		2.5%		8.1%
1968	8,444	10.0	$48	
1969	9,376	11.0	48	0.0
1970	9,764	4.1	46	-4.2
1971	9,352	-4.2	45	-2.2
1972	9,854	5.4	43	-4.4
1973	10,402	5.6	47	9.3
1974	10,753	3.4	64	36.2
1975	9,167	-14.7	94	46.9
1976	10,378	13.2	96	2.1
1977	10,573	1.9	97	1.0

SOURCE: Department of Commerce

GRAPH 2-1
CHLORINE PRODUCTION AND PRICE



SOURCE: Department of Commerce

TABLE 2-2

CHLOR-ALKALI PRODUCING COMPANIES, PLANTS, AND CAPACITIES

Companies and Plant Locations (Dec. 1980)	Annual Chlorine Capacity (Jan. 1979) (1000 tons)	Type Of Process	Year Built (Year Cells Installed)
AMAX Specialty Metals Corporation	20		
Rowley, UT		6	1977
BASF Wyandotte Corporation	179		
Geismar, LA		1	1959, 1969
Brunswick Chemical Company	30		
Brunswick, GA		1	1967
Champion International Corporation	51		
Canton, NC		1	1916
Houston, TX		1	1936
Convent Chemical Corp. (B.F. Goodrich)	128		
Calvert City, KY		2	1966
Diamond Shamrock Chemical Company	1,335		
LaPorte, TX		1	1974
Delaware City, DE		2	1965
Mobile, AL		2	1964
Muscle Shoals, AL		2	1952
Deer Park, TX		1,2	1938
ow Chemical Company	4,133		
Freeport, TX		1,6	1940
Midland, MI		1	1897
Pittsburg, CA		1	1917
Plaquemine, LA		1	1958
.I. duPont de Nemours & Co. Inc.	281		
Corpus Christi, TX		1	1974
Niagara Falls, NY		4	1898
thyl Corporation	68		
Baton Rouge, LA		4	1938
IC Corporation	292		
S. Charleston, WVA		1	1916 (1973)
rmosa Plastics Corporation USA	172		
Baton Rouge, LA		1	1937 (1968)

TABLE 2-2
(Continued)

CHLOR-ALKALI PRODUCING COMPANIES, PLANTS, AND CAPACITIES

Companies and Plant Locations (Dec. 1980)	Annual Chlorine Capacity (Jan. 1979) (1000 tons)	Type Of Process	Year Built (Year Cells Installed)
Fort Howard Paper Company	124		
Green Bay, WI		1	1968
Muskogee, OK		7	1980
General Electric	55		
Mt. Vernon, IN		1	1976
Georgia-Pacific Corporation	720-825		
Bellingham, WA		2	1965
Plaquemine, LA		1	1975
Hercules	31		
Hopewell, VA		1	1939
Hooker Chemical Corporation	1,137		
Montague, MI		1	1954
Niagara Falls, NY		1	1898 (1974, 1978)
Tacoma, WA		1	1929
Taft, LA		1	1966 (1975)
Hooker-IMC Joint Venture	47		
Niagara Falls, NY		3	1971
International Minerals and Chemical Corporation	119		
Ashtabula, OH		3	1963
Orrington, ME		2	1967
Kaiser Aluminum and Chemical Corporation	205		
Gramercy, LA		1	1958
Linden Chlorine Products, Corporation	504		
Acme, NC		2	1963
Brunswick, GA		2	1957
Linden, NJ		2	1956 (1963, 1969)
Moundsville, WVA		2	1953
Syracuse, NY		1,2	1927 (1-1968, 1977) (2-1953)
Mobay Chemical Corporation	90		
Baytown, TX		5	1972
Monsanto Company	44		
Sauget, IL		2	1922

TABLE 2-2
(Continued)

CHLOR-ALKALI PRODUCING COMPANIES, PLANTS, AND CAPACITIES

Companies and Plant Locations (Dec. 1980)	Annual Chlorine Capacity (Jan. 1979) (1000 tons)	Type Of Process	Year Built (Year Cells Installed)
Olin Corporation	948		
Augusta, GA		2	1965
Charleston, TN		2	1962
McIntosh, AL		1,2	1952 (1-1977, 1978)
Niagara Falls, NY		2	1897 (1960)
Pennwalt Corporation	462		
Calvert City, KY		2	1953 (1967)
Portland, OR		1	1947 (1967)
Tacoma, WA		1	1929
Wyandotte, MI		1	1898 (1960)
PPG Industries, Inc.	1,523		
Barberton, OH		1	1936
Lake Charles, LA		1,2	1947 (1-1977, 1980) (2-1969)
New Martinsville, WVA		1,2	1943 (2-1958)
RMI Company	77		
Ashtabula, OH		4	1949
Shell Chemical Company	77		
Deer Park, TX		1	1966
Stauffer Chemical Company	348		
Henderson, NV		1	1942 (1976)
Lemoyne, AL		2	1965
St. Gabriel, LA		2	1970
Titanium Metals Corp. of America			
Henderson, NV		6	1943
Vertac Chemical Company	33		
Vicksburg, MS			1962
Vulcan Materials Company	544		
Denver City, TX		1	1947
Geismar, LA		1	1976
Wichita, KS		1	1952 (1975)
Port Edwards, WI		2	1967
Weyerhauser Company	140		
Longview, WA		1	1957 (1975)

TABLE 2-2
(Continued)

CHLOR-ALKALI PRODUCING COMPANIES, PLANTS, AND CAPACITIES

KEY

Type of process:

1-Diaphragm cell electrolytic plant producing chlorine, caustic soda and other products.

2-Mercury cell electrolytic plant producing chlorine, caustic soda and other products.

3-Mercury cell electrolytic plant producing chlorine and caustic potash but not caustic soda.

4-Electrolytic plant producing metallic sodium and chlorine.

5-Electrolytic plant producing chlorine ad hydrogen from hydrochloric acid.

6-Electrolytic plant producing magnesium and chloride from molten magnesium chloride.

SOURCES: Stanford Research Institute, Directory of Chemical Producers, 1979
The Chlorine Institute, North American Chlor-Alkali Industry Plants and Production Data Book, January 1981

TABLE 2-3a

ESTIMATED COST OF MANUFACTURING CHLORINE - MERCURY PROCESS*

(Mid-1978 Dollars)

Plant Capacity	28,000 tons/year
Annual Production	21,000 tons/year (75% capacity utilization)
Fixed Investment	$15.3 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.819 tons	10.00	18.20
- Other			10.80
• Utilities			
- Cooling Water	7.42 mgal	.10	.70
- Steam	2.04 mlb	3.25	6.60
- Process Water	1.1 mgal	.75	.80
- Electricity	3500 kWh	.03	91.00
Total Variable Costs			$128.10
SEMI-VARIABLE COSTS			
• Labor			37.50
• Maintenance			29.10
Total Semi-Variable Costs			$ 66.60
FIXED COSTS			
• Plant Overhead			15.30
• Depreciation			72.60
• Taxes & Insurance			14.50
Total Fixed Costs			$102.40
TOTAL COST OF MANUFACTURE			$297.10
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$167.10

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 2-3b

ESTIMATED COST OF MANUFACTURING CHLORINE - MERCURY PROCESS*

(Mid-1978 Dollars)

Plant Capacity	140,000 tons/year
Annual Production	105,500 tons/year (75% capacity utilization)
Fixed Investment	$47.1 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.819 tons	10.00	18.20
- Other			10.80
• Utilities			
- Cooling Water	7.42 mgal	.10	.70
- Steam	2.04 mlb	3.25	6.60
- Process Water	1.1 mgal	.75	.80
- Electricity	3500 kWh	.03	91.00
Total Variable Costs			$128.10
SEMI-VARIABLE COSTS			
• Labor			27.20
• Maintenance			17.90
Total Semi-Variable Costs			$ 45.10
FIXED COSTS			
• Plant Overhead			11.60
• Depreciation			44.80
• Taxes & Insurance			9.00
Total Fixed Costs			$ 65.40
TOTAL COST OF MANUFACTURE			$238.60
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$108.60

SOURCE: Contractor and EEA estimates

See Appendix C

TABLE 2-3c

ESTIMATED COST OF MANUFACTURING CHLORINE - MERCURY PROCESS*
(Mid-1978 Dollars)

Plant Capacity	280,000 tons/year
Annual Production	210,500 tons/year (75% capacity utilization)
Fixed Investment	$76.4 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.819 tons	10.00	18.20
- Other			10.80
• Utilities			
- Cooling Water	7.42 mgal	.10	.70
- Steam	2.04 mlb	3.25	6.60
- Process Water	1.1 mgal	.75	.80
- Electricity	3500 kWh	.03	91.00
Total Variable Costs			$128.10
SEMI-VARIABLE COSTS			
• Labor			23.70
• Maintenance			14.50
Total Semi-Variable Costs			$ 38.20
FIXED COSTS			
• Plant Overhead			10.60
• Depreciation			36.40
• Taxes & Insurance			7.30
Total Fixed Costs			$ 54.30
TOTAL COST OF MANUFACTURE			$220.60
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$ 90.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 2-4a

ESTIMATED COST OF MANUFACTURING CHLORINE-DIAPHRAGM PROCESS*
(Mid-1978 Dollars)

Plant Capacity	28,000 tons/year
Annual Production	21,000 tons/year (75% capacity utilization)
Fixed Investment	$13.9 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.76 tons	10.00	17.60
- Other			2.70
• Utilities			
- Cooling Water	46.75 mgal	.10	4.70
- Steam	12.4 mlb	3.25	40.30
- Process Water	5.38 mgal	.75	4.00
- Electricity	2,900 kWh	.03	75.40
Total Variable Costs			$144.70
SEMI-VARIABLE COSTS			
• Labor			42.80
• Maintenance			26.40
Total Semi-Variable Costs			$ 69.20
FIXED COSTS			
• Plant Overhead			17.30
• Depreciation			66.00
• Taxes & Insurance			13.20
Total Fixed Costs			$ 96.50
TOTAL COST OF MANUFACTURE			$310.40
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$180.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 2-4b

ESTIMATED COST OF MANUFACTURING CHLORINE - DIAPHRAGM PROCESS*
(Mid-1978 Dollars)

Plant Capacity	140,000 tons/year
Annual Production	105,500 tons/year (75% capacity utilization)
Fixed Investment	$42.8 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.76 tons	10.00	17.60
- Other			2.70
• Utilities			
- Cooling Water	46.75 mgal	.10	4.70
- Steam	12.4 mlb	3.25	40.30
- Process Water	5.38 mgal	.75	4.00
- Electricity	2,900 kWh	.03	75.40
Total Variable Costs			$144.70
SEMI-VARIABLE COSTS			
• Labor			29.30
• Maintenance			16.30
Total Semi-Variable Costs			$ 45.60
FIXED COSTS			
• Plant Overhead			12.40
• Depreciation			40.70
• Taxes & Insurance			8.10
Total Fixed Costs			$ 61.20
TOTAL COST OF MANUFACTURE			$251.50
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$121.50

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 2-4c

ESTIMATED COST OF MANUFACTURING CHLORINE - DIAPHRAGM PROCESS*
(Mid-1978 Dollars)

Plant Capacity	280,000 tons/year
Annual Production	210,500 tons/year (75% capacity utilization)
Fixed Investment	$69.5 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Salt	1.76 tons	10.00	17.60
- Other			2.70
• Utilities			
- Cooling Water	46.75 mgal	.10	4.70
- Steam	12.4 mlb	3.25	40.30
- Process Water	5 38 mgal	.75	4.00
- Electricity	2,900 kWh	.03	75.40
Total Variable Costs			$144.70
SEMI-VARIABLE COSTS			
• Labor			27.00
• Maintenance			13.20
Total Semi-Variable Costs			$ 40.20
FIXED COSTS			
• Plant Overhead			11.80
• Depreciation			33.10
• Taxes & Insurance			6.60
Total Fixed Costs			$51.50
TOTAL COST OF MANUFACTURE			$236.40
Coproduct credit: Caustic soda			130.00
NET PRODUCTION COST			$106.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

The location of chlorine plants usually is determined by access to inexpensive sources of power and salt. Electricity can represent as much as 60 percent of total manufacturing costs. The plants which use chlorine usually are located near their critical inputs such as petrochemicals and natural gas. This has led to a large number of plants being located along the Gulf coast and in the Pacific Northwest where hydroelectric power has, historically, been plentiful. Because of chlorine's relatively low value, transportation costs also play an important role. To control these costs, shipping distances are limited.

2.1.3 Competition

Chlorine and caustic soda compete predominantly on the basis of price. (Chlorine comes in one grade--technical--99.9 percent). Because they are high tonnage/low value products, transportation charges are important and producers have tried to locate near their markets. About half of the chlorine produced is consumed in Texas and Louisiana. The more efficient Gulf Coast producers can economically ship their chlorine well into the central regions of the country.

Although there is some concentration in the chlorine industry (the top four producers account for more than half of production), pricing of the remaining noncaptive chlorine (40 percent) is competitive. In 1978, the f.o.b. list price was $135 per ton, while spot prices went as low as $80 per ton. This spread illustrates the wide variations common in spot prices. In 1977, under similar conditions, the average price was $97 per ton, indicating considerable discounting. Low capacity utilization, plant expansions, uneven caustic demand, and rapidly rising costs complicate chlorine pricing patterns.

Capacity utilization, historically in the mid-90 percent range, dropped to the 75 to 80 percent range around 1974-75 and is not expected to recover very much in the foreseeable future. This is due to the large capacity additions recently made and in progress. This type of low capacity utilization leads to "weak prices" (often in the form of discounts on list prices) as the individual firms become more competitive for market shares.

Although no one substitute is likely to take over all of chlorine's diverse uses, several substitutes may make some inroads. For example, in chlorine's largest single market (polyvinyl chloride--17 percent of Cl_2 consumption), hydrogen chloride can be substituted for chlorine. In pulp and paper, there is increasing use of sodium chlorate and oxygen bleaching methods. The manufacture of aerosols composed of fluorocarbons was prohibited after October 1978. Even the water treatment market is experiencing competition from chemicals such as ozone.

Because of chlorine's low value, imports and exports are negligible (less than one percent). Caustic soda exports however are expected to equal five percent of 1978 production. Increased domestic demand has reduced the caustic soda available for export.

While some chlorine uses are declining, others such as urethane, polyester, and PVC are growing. Overall, a growth rate of three to four percent appears likely.

The cost of producing chlorine and caustic soda has been rising since 1969, with a particularly steep rise between 1973 and 1975 (primarily due to rapid electricity rate increases). Chlorine prices rose in response to these cost increases, with a high degree of pass-through until 1976. In the 1967 to 1975 period, electricity prices increased by 9.1 percent/ year, chlorine prices by 7.9 percent/year, and value of shipments by 11.2 percent/year, while the consumer price index rose 6.1 percent/year. However, this situation changed after 1975. Prices did not increase through 1975, 1976, 1977, and much of 1978. Thus the real price was falling while energy, salt, and other costs continued to rise. However, chlorine prices alone do not cover the full cost of chlorine-caustic soda production. Currently, the caustic soda market is stronger than the chlorine market and consequently in a better position to support price increases. Late in 1978, one of the main merchant producers raised their price by $10/ton. Actual selling prices were around $110 to $125 per ton. Several producers followed suit and the price increase may be successful (sometimes price increases are remanded). If it is successful, it will temporarily ease producers' profitability problems.

2.1.4 Economic Outlook

2.1.4.1 Revenue

Chlorine sales forecasts generally call for annual growth rates of 3 to 7 percent with expected values around 3.5 percent. The last decade (1967-76) saw annual growth rates of 3.1 percent, so recent forecasts show a small increase in the growth rate. Recent and planned capacity additions have significantly added to capacity and will continue to do so. As discussed, chlorine prices have been weak for three years. With capacity utilization likely to remain at relatively low levels, price recovery will be slow.

2.1.4.2 Manufacturing Costs

Manufacturing costs for chlorine are increasing due to rapidly increasing energy prices. A total of 99.5 percent of chlorine is produced by the electrolytic process, typically using 2,600 to 3,300 kwh per metric ton of chlorine (plus 1.13 metric tons of NaOH and 315 m^3 of H_2). Energy costs currently represent 45 to 60 percent of production costs and may reach the 75 percent level in the early 1980's due to the exceptionally rapid increases in energy prices. Increased energy costs will affect the chlorine end products as well, since many require petrochemicals as feedstocks. For example, 55 percent of the chlorine produced is used in chlorinating organic compounds. As the relative prices in these products rise due to rising feedstock costs, users will seek less expensive substitutes. This will also reduce chlorine demand as these end products become less competitive internationally.

Because chlorine is such a critical input to a great number of other chemicals, many manufacturers are conducting research on reducing costs and perhaps the energy intensity of chlorine manufacture. For example, Diamond Shamrock and DuPont are working jointly on a new "membrane cell" technology. Diamond Shamrock feels that membrane cells will be more competitive at low capacity plants, with diaphragm cells remaining more efficient at high capacity plants. The membrane cell produces a salt-free concentrated caustic, thus reducing the need for evaporation. Further development of this new technology may yield significant savings. Experimentation is continuing on their two-membrane cell installations in Painesville, Ohio, and Muscle Shoals, Alabama.

Other researchers are studying different types of membranes, different anodes, and varying cell structures. In addition, chlorine recovery from hydrogen chloride (HCl) may become increasingly attractive. HCl often is released in the chlorination of organic chemicals. As chlorine prices continue to rise, the benefits from chlorine recovery will increase.

2.1.4.3 Profit Margins

Chlorine is predominantly a captively produced chemical. As such, its economics are intricately tied up with those of the end products such as PVC, refrigerants, and polyurethane. For most producers, profit margins on chlorine are of secondary importance to the profitability of the whole product line. Although prices may be "weak" on some of these end products, strong long run demand and efficient processes are likely to contribute significant earnings to the producers.

2.1.5 Characterization Summary

Chlorine is an important high volume chemical with a variety of end uses. These include:

- **Polyvinyl chloride (17 percent of chlorine consumption) - a widely used plastic**
- **Propylene oxide - used in the production of polyurethane foam products**
- **Ethylene dichloride - an intermediate used in the manufacture of polyvinyl chloride.**

Chlorine is produced by over 30 firms in the U.S. Of the 10.6 million tons produced in 1977, almost two-thirds was used captively by the producers. Because products are energy intensive, manufacturing costs are likely to rise during the next few years. Since most chlorine production is used captively, its profitability is determined by the profitability of its end products. Demand for products using chlorine in their manufacture is expected to remain strong enough to justify continued chlorine production.

2.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the chlorine subcategory to comply with PSES and BAT effluent control standards. The technical contractor has designed effluent control technologies which can be used to achieve these standards. The cost of each technology is used to make an assessment of the economic impacts that effluent limitations will have on the subcategory. In addition, the impacts of combined effluent control and hazardous waste disposal costs are examined for chlorine plants affected by the Resource Conservation and Recovery Act's Interim Status Standards (RCRA-ISS).

There are 25 mercury cell chlorine plants. Two plants are indirect dischargers, both of which are already in compliance with PSES limitations and will therefore incur no incremental effluent control costs. The remaining 23 mercury cell plants will incur additional costs above BPT treatment for compliance with BAT limitations. All mercury cell plants will incur additional hazardous waste disposal costs in order to comply with RCRA-ISS requirements. However, not all of these hazardous waste disposal costs are attributable to effluent limitations.

There are 36 diaphragm cell chlorine plants. One plant is an indirect discharger not currently pretreating wastewater. Therefore, this plant will incur BPT treatment costs, which are equivalent to PSES for this subcategory. The remaining chlorine diaphragm cell plants will incur only the incremental costs of BAT for compliance with effluent limitations (BPT effluent limitations are already in effect and are being met by all direct discharge diaphragm cell plants). Only diaphragm cell plants using graphite anodes will incur additional hazardous waste disposal costs in order to comply with RCRA-ISS requirements.

Thus, the impact analysis will examine:

1) The impacts of the incremental costs required for direct discharge mercury cell plants to comply with BAT effluent limitations

2) The impacts of the combined cost of compliance with effluent limitations and RCRA-ISS requirements for all mercury cell plants

3) The impacts of pretreatment costs for the single diaphragm cell indirect discharger

4) The impacts of the incremental costs required for direct discharge diaphragm cell plants to comply with BAT effluent limitations

5) The impacts of the combined cost of compliance with effluent limitations and RCRA-ISS requirements for chlorine diaphragm cell plants using graphite anodes.

2.2.1 Pollution Control Technology and Costs

Almost all chlorine is manufactured using one of the following processes:

- Diaphragm cell - this process accounts for 74 percent of all chlorine manufacture and is used in 36 plants.
- Mercury cell - there are currently 25 plants which employ this technology to produce 20 percent of all chlorine. Production by this process is declining due to environmental problems.

The remaining six percent is produced using a number of other technologies for which no effluent control costs will be required. Treatment systems for the two major processes will be considered separately.

2.2.1.1 Mercury Cell Plants

In mercury process plants, the raw waste streams must be segregated into brine mud and mercury bearing process wastes before treatment.

The mercury bearing wastewater results from several sources: cell room wastes, chlorine condensate, spent sulfuric acid, tail gas scrubber liquid, caustic filter washdown, and hydrogen condensate. The toxic pollutants found in these wastewaters include: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, thallium, and zinc. The model plants assume a unit flow of 2.1 m^3/kkg of product.

For mercury cell plants, pollution control costs were estimated by the technical contractor for two levels of effluent treatment. BPT treatment, now in place under Best Practicable Technology regulations (BPT), requires three steps:

- Effluent separated into brine mud and mercury-bearing waste streams
- Brine mud is settled in a lagoon

- Mercury stream is collected and pH adjusted; sodium bisulfite is added to precipitate mercury; and flow is filtered

BAT treatment requires a dechlorination step. In addition, plants will have to meet more stringent mercury limitations in order to comply with BAT.

Pollution control cost estimates were developed for three sizes of mercury cell plants. Model plant annual production rates are 21,000, 105,500, and 210,500 tons per year. Approximately 60 percent of diaphragm and mercury cell chlorine production occurs in plants within the production range specified by the model plants. Those plants falling beyond the range are reasonably approximated by the largest or smallest model plants.

Estimates of the investment and operating costs of BPT and BAT treatment for mercury cell model plants are found in Table 2-5a. Costs of compliance with RCRA-ISS requirements are also included in the table. Note that the RCRA costs account for all hazardous wastes produced by the model plant, not just the incremental wastes attributable to BAT treatment. The analysis thus overstates the RCRA costs impacts which are directly attributable to BAT.

Manufacturing costs for mercury process chlorine plants were estimated to be $177.20, $111.50, and $92.60 per ton of chlorine for the small, medium, and large model plants respectively. These estimates are based on the estimates presented in Table 2-3 and include the costs of meeting BPT effluent limitations. Financial parameters are summarized in Table 2-6a.

Investment and annual control costs for mercury cell chlorine producers are summarized in Table 2-7a. These costs are based on the model plant pollution control costs and current industry production levels. Subcategory compliance with BAT limitations would require additional annua-

TABLE 2-5a: POLLUTION CONTROL COSTS

Chemical: Chlorine-Mercury Cell

Model Plant Production (tons/year)	BAT*		RCRA-ISS			
	Investment Costs	Annual Operating Costs	Capital Costs	Initial Costs	Annual Operating Costs	Total Closure Fund[+]
21,000	$34,914	$28,039	$67,008	$6,404	$29,269	$329,239
105,500	60,720	39,094	68,730	6,404	53,396	421,897
210,500	91,080	63,640	71,312	6,404	73,907	480,518

*BAT costs represent incremental costs over BPT costs.

[+] The closure fund will be built up over 20 years.

SOURCE: Technical Contractor

Table 2-6a MANUFACTURING COSTS

Chemical: Chlorine-Mercury Cell

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs* Per Ton
21,000	$15,300,000	$177.20
105,500	47,100,000	111.50
210,500	76,400,000	92.60

*Includes the cost of meeting BPT effluent limitations.

Note: All costs are in mid-1978 dollars.

TABLE 2-7a

SUBCATEGORY COMPLIANCE COSTS

Chemical: Chlorine-Mercury Cell

	BAT			BAT plus RCRA-ISS		
Model Plant Production (Tons/Year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)
21,000	278,000	$244,398	$469,820	311,000	$780,462	$1,604,970
105,500	1,456,000	850,080	728,000	1,522,000	1,881,030	2,310,880
210,500	376,000	182,160	150,400	376,000	324,784	394,800
TOTAL	2,110,000*	$1,276,638	$1,348,220	2,209,000+	$2,986,276	$4,310,650

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*Excludes two indirect dischargers that are already meeting PSES regulations and will incur no additional costs for compliance with effluent guidelines.

+ Includes two indirect dischargers that will incur RCRA-ISS costs although they will not incur additional effluent control costs.

lized costs of approximately $1.3 million. The additional cost required to comply with RCRA-ISS costs increases the subcategory's total annualized costs to $4.3 million.

2.2.1.2 Diaphragm Cell Plants

In the diaphragm cell process, segregation of waste streams is required before treatment. The streams are segregated into brine mud, cell wash, and other metals-bearing process water. The brine mud stream is identical in content to the brine mud stream resulting from mercury cell production, and a unit flow of 8.8 m^3/kkg was assumed.

For the diaphragm process chlorine plant, the technical contractor has developed technologies designed to meet BPT and BAT levels of removal.

BPT requires three treatment steps:

- o Equalization: Brine mud settled in a lagoon
- o Alkaline Precipitation: Metal is precipitated
- o Settling: After filtration, solids are landfilled

BAT adds dual-media filtration and dechlorination to BPT treatment.

Pollution control cost estimates were developed for three sizes of diaphragm cell plants. Model plant annual production rates are the same as for mercury cell plants: 21,000, 105,500, and 210,500 tons per year.

Estimates of the investment and operating costs of BPT and BAT treatment for diaphragm cell model plants are found in Table 2-5b. Compliance with PSES limitations will require BPT treatment only. Costs of compliance with RCRA-ISS requirements are presented separately since only the six plants with graphite anodes will incur these additional costs. Note that as in the case of the mercury-cell plants, the RCRA-ISS costs account for disposal of all hazardous wastes produced by the model plants. The analysis thus overstates the incremental RCRA costs which are directly attributable to the effluent limitations.

The manufacturing costs used to evaluate the impacts of pollution control costs on diaphragm plants are summarized in Table 2-6b. Manufacturing cost estimates are presented with and without the costs of BPT treatment.

Investment and annualized effluent control costs for diaphragm cell chlorine producers are summarized in Table 2-7b. These costs are based on the model plant pollution control costs and current industry production levels. The table presents the costs required for compliance with both PSES and BAT limitations. Currently, there is only one indirect discharge plant and its estimated annual control costs for meeting PSES limitations are $570,580. Direct dischargers' compliance with BAT limitations would require additional annual costs of approximately $4.05 million.

Tables 2-7c presents subcategory compliance costs separately for the six diaphragm cell plants which will incur RCRA-ISS costs; Table 2-7d presents subcategory compliance costs for the remaining 30 plants which will not be affected by RCRA-ISS. Table 2-7c indicates that compliance with both effluent and RCRA-ISS regulations by graphite anode diaphragm cell plants will require approximately $0.4 million annually. Adding these costs to the effluent control costs shown in Table 2-7d yields a total annual cost of approximately $4.1 million required for diaphragm cell plants to comply with both effluent control and RCRA-ISS regulations.

2.2.2 Model Plant Analysis

This section outlines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

- o Price Rise - the calculation of the price increase required to fully recover the increased pollution control costs.

TABLE 2-5b: POLLUTION CONTROL COSTS

Chemical: Chlorine-Diaphragm Cell

Model Plant Production (tons/year)	BPT/PSES Capital Investment	BPT/PSES Annual Operating Costs	BAT Capital Investment	BAT Annual Operating Costs	RCRA-ISS* Capital Cost+	RCRA-ISS* Initial Cost	RCRA-ISS* Annual Operating Costs	RCRA-ISS* Total Closure Fund+
21,000	$309,000	$174,000	$ 65,274	$32,286	0	$1,712	$4,829	0
105,500	625,000	243,000	106,260	52,614	0	1,712	7,335	0
210,500	909,000	$313,000	164,703	73,711	0	1,712	12,733	0

*Only six diaphragm cell plants will incur RCRA-ISS costs.

+ For the model plant costs shown here, it is assumed that plants will dispose of their wastes in an off-site landfill; therefore no capital or closure fund costs are shown for compliance with RCRA-ISS requirements.

SOURCE: Technical Contractor

TABLE 2-6b: MANUFACTURING COSTS

Chemical: Chlorine-Diaphragm Cell

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs Per Ton	Manufacturing Costs Per Ton Including BPT Costs
21,000	$13,900,000	$180.40	$191.90
105,500	42,800,000	121.50	125.10
210,500	69,500,000	106.40	108.80

Note: All costs are in mid-1978 dollars.

TABLE 2-7b

SUBCATEGORY COMPLIANCE COSTS

Chemical: Chlorine-Diaphragm Cell

Annual Production: 6,367,000 tons/year*

	BPT/PSES			BAT		
Model Plant Production (Tons/Year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)
21,000	NA	NA	NA	320,000	$652,740	$707,200
105,500	NA	NA	NA	1,620,000	1,593,900	1,166,400
210,500	235,000	$909,000	$570,580	4,192,000	1,647,030	2,179,840
TOTAL	235,000	$909,000	$570,580	6,132,000	$3,893,670	$4,053,440

* Includes 421,000 tons also affected by RCRA.

NA: Not applicable--no plants incurring costs.

TABLE 2-7c

SUBCATEGORY COMPLIANCE COSTS -- BAT plus RCRA-ISS

Chemical: Chlorine-Diaphragm Cell (Graphite Anode)

Annual Production Affected By RCRA-ISS: 421,000 tons

Model Plant Production (tons/year)	Estimated Annual Production by Affected Plants (tons)	BAT plus RCRA-ISS	
		Investment Costs	Annualized Costs ($/year)
21,000	42,000	$195,822	$103,320
105,500	189,000	222,520*	149,310
210,500	190,000	164,703	110,200
TOTAL	421,000	$583,045	$362,830

*These investment costs include the incremental captial cost of $10,000 required by one of six graphite-anode diaphragm cell plants.

TABLE 2-7d

SUBCATEGORY COMPLIANCE COSTS

Chemical: Chlorine-Diaphragm Cell

Annual Production NOT Affected by RCRA-ISS

	BPT/PSES			BAT		
Model Plant Production (Tons/Year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs
21,000	NA	NA	NA	278,000	$456,918	$614,380
105,500	NA	NA	NA	1,431,000	1,381,380	1,030,320
210,500	235,000	$909,000	$570,580	4,002,000	1,482,327	2,081,040
TOTAL	235,000	$909,000	$570,580	5,711,000	$3,320,625	$3,725,740

NA: Not applicable--no plants incuring costs.

- Profitability Decline - the maximum decline in profitability that would result if no price increase were possible.

- Price Elasticity of Demand - a subjective estimate based on information developed in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.

- The Capital Ratio - the ratio of pollution capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

The following sections address the impacts of BAT costs for direct discharge plants. In addition, a model plant analysis of the impacts of pretreatment standards on the single diaphragm cell indirect discharger is presented. Finally, the impacts of the combined costs of compliance with effluent control and RCRA-ISS requirements are examined for the affected chlorine plants.

2.2.2.1 Price Rise Analysis

Two chlorine production processes are analyzed, each requiring different pollution control technologies. For both processes, the price rise analysis assumes complete pass-through of pollution control costs.

Mercury Cell

The price rise required of mercury cell plants is shown in Table 2-8. The price increases required to recover the incremental costs of BAT treatment range from 0.36 percent for the large model size to 1.54 percent for the small model plant. To recover both effluent control and RCRA-ISS costs, chlorine mercury cell plants would require price increases of 0.95 percent to 4.85 percent, depending on size.

Diaphragm Cell

The price increase required of diaphragm cell plants is shown in Table 2-9. Depending on size, a 2.2 to 10.4 percent price increase would be required to fully recover pretreatment (PSES) costs. For direct dischargers, the price increase required to recover BAT costs ranges from 0.47 to 2.01 percent. The required price increase for graphite anode diaphragm cell plants to recover both effluent control and RCRA-ISS costs is slightly higher, ranging from 0.53 to 2.24 percent.

2.2.2.2 Profitability Analysis

The profitability analysis assumes no price pass-through is possible and calculates the resulting decline in the return on investment (ROI) and the internal rate of return (IRR) attributable to the costs of pollution control.

Mercury Cell

For the two larger mercury cell model plants, profitability declines resulting from effluent control costs are minimal (less than 0.1 percentage point or less than one percent of baseline profitability). The smallest model plant size incurs a significant decline in profitability of 0.21 percentage points or 24.42 percent of baseline profitability (based on ROI). (See Table 2-10a).

The additional costs required for RCRA-ISS compliance result in higher profitability declines, ranging from 0.17 to 0.67 percentage points. For the two larger model plant sizes, this represents a profitability decrease of less than 2.5 percent. For the smallest model plant size, the profitability decline represents 77.91 percent of baseline profitability. Table 2-10b summarizes these results.

TABLE 2-8

PERCENTAGE PRICE RISE

Chemical: Chlorine-Mercury Cell

Price: $110/ton

Model Plant Production (tons/year)	BAT	RCRA-ISS
21,000	1.54%	4.85
105,500	0.45	1.40
210,500	0.36	0.95

TABLE 2-9

PERCENTAGE PRICE RISE

Chemical: Chlorine-Diaphragm Cell

Price: $110/ton

Model Plant Production (tons/year)	BPT/PSES	BAT	BAT plus RCRA-ISS*
21,000	10.4%	2.01%	2.24%
105,500	3.3	0.65	0.72
210,500	2.2	0.47	0.53

*Only six chlorine-diaphragm cell plants will incur RCRA-ISS costs.

TABLE 2-10a

PROFITABILITY CHANGE

Chemical: Chlorine-Mercury Cell

Level: BAT

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	0.86%	0.65%	-0.21% (-24.42%)	*	*	*
105,500	10.63	10.58	-0.05 (-0.47%)	9.93%	9.86%	-0.07% (-0.70%)
210,500	13.79	13.73	-0.06 (-0.44%)	13.78	13.72	-0.06 (-0.44%)

*Negative profitability

TABLE 2-10b

PROFITABILITY CHANGE

Chemical: Chlorine-Mercury Cell

Level: BAT plus RCRA-ISS

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	0.86%	0.19%	-0.67 (-77.91%)	*	*	*
105,500	10.63	10.46	-0.17 (-1.60%)	9.93%	9.69%	-0.24 (-2.42%)
210,500	13.79	13.63	-0.16 (-1.16%)	13.78	13.61	-0.17 (-1.23%)

*Negative profitability

Diaphragm Cell

Pretreatment costs for diaphragm cell indirect dischargers would result in profitability declines ranging from 0.30 to 1.40 percentage points (as measured by ROI) or approximately 2.6 to over 182 percent of baseline profitability (see Table 2-11a). The profitability declines resulting from BAT costs, shown in Table 2-11b, range from 0.07 to 0.25 percentage points (based on ROI) or 1.54 to 8.96 percent of baseline profitability. The combined effects of both BAT and RCRA-ISS costs on the six graphite anode plants would result in slightly greater profitability declines of 0.08 to 0.29 percentage points (as measured by ROI) representing 0.72 to 10.39 percent of baseline profitability levels (see Table 2-11c).

2.2.2.3 Price Elasticity of Demand

Chlorine is an essential input for many downstream chemicals and end products. There are few competitive substitutes for chlorine in these uses. In addition, over 60 percent of chlorine production is captive. Thus, cost increases resulting from pollution control regulations will be partly allocated to downstream products. Therefore, this analysis assumes demand is relatively inelastic. (See Sections 2.1.1, Demand, and 2.1.3, Competition, for a complete analysis.)

2.2.2.4 Capital Analysis

The capital investments required for compliance with effluent control and RCRA-ISS regulations are given in Tables 2-5a, and 2-5b.

Mercury Cell

Table 2-12 summarizes the results of the capital analysis for chlorine mercury cell plants. For mercury cell plants, the capital costs of effluent control range from 0.12 to 0.23 percent of fixed investment in plant and equipment. The additional capital costs of RCRA-ISS regulations increase the capital requirements to 0.21 to 0.67 percent of plant investment.

Diaphragm Cell

Table 2-13 summarizes the results of the capital analysis for chlorine-diaphragm cell plants. The capital costs of PSES regulations represent 1.30 to 2.2 percent of fixed investment in plant and equipment. BAT capital costs represent 0.24 to 0.47 percent of fixed investment. For five of the six graphite anode plants, no incremental capital costs will be required for RCRA-ISS compliance; accordingly, their capital costs represent 0.24 to 0.47 percent of fixed investment. One graphite anode plant (corresponding to model size 2) will require additional capital costs of $10,000. For this plant the combined capital costs of effluent control and RCRA-ISS regulations represent approximately 0.27 percent of fixed investment, as shown in Table 2-13.

Since all capital costs represent less than two percent of fixed investment in place, they should not represent a significant problem to any chlorine manufacturer.

2.2.2.5 Closure Analysis

Tables 2-14 and 2-15 summarize the price elasticity of demand, price rise, and profitability decline for chlorine mercury cell and chlorine diaphragm cell model plants and compare these to EPA's closure criteria (see methodology description). Since production of chlorine is mostly captive, the demand for the chemical is relatively price inelastic for all model plants.

Mercury Cell

Table 2-14 summarizes the model plant closure analysis for chlorine mercury cell plants. The price increase required to recover BAT effluent control costs is less than one percent for the medium and large model plants. The price increase required by the small model plant exceeds one percent, and though the profitability decline (based on ROI) is less than one percentage point, the decrease in profitability is 24.42 percent of the baseline level.

TABLE 2-11a

PROFITABILITY CHANGE

Chemical: Chlorine-Diaphragm Cell

Level: PSES

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	-0.77%	-2.17	-1.40 (-181.8)	*	*	*
105,500	8.31%	7.54%	-0.77 (-9.3%)	7.43	6.61	-0.82 (-11.0%)
210,500	11.51%	11.21%	-0.30 (-2.61%)	11.10%	10.67%	-0.43 (-3.9%)

*Negative profitability.

Note: The baseline ROI and IRR shown here do not match the baseline ROI and IRR shown in Table 2-11b because the profitability shown here is based on plant operating costs without BPT.

TABLE 2-11b

PROFITABILITY CHANGE

Chemical: Chlorine-Diaphragm Cell

Level: BAT

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	-2.79%	-3.04%	-0.25 (-8.96%)	*	*	*
105,500	7.28%	7.12%	-0.16 (-2.20%)	6.30%	6.11%	-0.19 (-3.02%)
210,500	11.07%	11.00%	-0.07 (-1.54%)	10.52%	10.42%	-0.10 (-0.95%)

*Negative profitability.

TABLE 2-11c

PROFITABILITY CHANGE

Chemical: Chlorine-Diaphragm Cell

Level: BAT plus RCRA-ISS

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	-2.79%	-3.08%	-0.29 (-10.39%)	*	*	*
105,500	7.28%	7.10%	-0.18 (-2.47%)	6.30%	6.09%	-0.21 (-3.33%)
210,500	11.07%	10.99%	-0.08 (-0.72%)	10.52%	10.41%	-0.11 (-1.05%)

*Negative profitability.

TABLE 2-12

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Chlorine-Mercury Cell

	Model Plant Production (tons/year)		
Level of Removal	21,000	105,500	210,500
BAT	0.23%	0.13%	0.12%
BAT plus RCRA-ISS	0.67	0.27	0.21

TABLE 2-13

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Chlorine-Diaphragm Cell

	Model Plant Production (tons/year)		
Level of Removal	21,000	105,500	210,500
PSES/BPT	2.2%	1.5%	1.3%
BAT	0.47	0.25	0.24
BAT plus RCRA-ISS	0.47	0.25-0.27	0.24

TABLE 2-14

IMPACT SUMMARY

Chemical: Chlorine-Mercury Cell

CLOSURE CRITERIA	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater Than 10% of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE (% DECLINE)	CLOSURES
BAT	21,000	Low	1.54%	0.21%* (24.42%)*	no
	105,500		0.45	0.07 (0.70)	no
	210,500		0.36	0.06 (0.44)	no
BAT plus RCRA-ISS	21,000	Low	4.85%	0.67%* (77.91%)*	no
	105,500		1.40	0.24 (2.42)	no
	210,500		0.95	0.17 (1.23)	no

*Based on ROI.

SOURCE: EEA estimates.

TABLE 2-15

IMPACT SUMMARY

Chemical: Chlorine-Diaphragm Cell

	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
CLOSURE CRITERIA DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1%	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE (% DECLINE)	CLOSURES
PSES	21,100	Low	10.4%	1.4* (181.8%)*	no
	105,500		3.3	0.77 (9.3)	no
	210,500		2.2	0.3 (2.61)	no
BAT	21,000	Low	2.01%	0.25%* (8.96%)*	no
	105,000		0.65	0.19 (3.02)	no
	210,500		0.47	0.10 (0.95)	no
BAT plus RCRA-ISS**	21,000	Low	2.24%	0.29%* (10.39%)*	no
	105,500		0.72	0.21 (3.33)	no
	210,500		0.53	0.11 (1.05)	no

* Based on ROI.

**Only six chlorine diaphragm cell plants will incur RCRA-ISS costs.

SOURCE: EEA estimates.

The additional costs of RCRA-ISS requirements increase the price rise to above one percent for the small and medium plants and to only slightly less than one percent for the large plant. Profitability declines for the medium and large model plants are less than one-fourth of one percentage point (and less than three percent of baseline profitability).

According to EPA's closure criteria, medium and large model plants are not likely closure candidates even with the imposition of RCRA-ISS costs. However, for the small model plant the profitability decline resulting from BAT costs is 24 percent and increases to almost 78 percent with the addition of RCRA-ISS costs. The relatively inelastic demand should premit the low projected price increase to be completely passed through to consumers, thereby mitigating the profitability impacts of pollution control costs on the small model plant. The implications of these model plant results for actual mercury cell plants are discussed in more detail in Section 2.2.3, Industry Impacts.

Diaphragm Cell

Table 2-15 summarizes the model plant closure analysis for chlorine diaphragm cell plants. For indirect dischargers, the price increase required to recover PSES costs exceeds one percent for all model sizes. The profitability decline exceeds one percentage point and/or ten percent of baseline profitability for the small plant while the profitability decline is under one percentage point and less then ten percent of baseline profitability for the large and medium-sized model plants. The impacts of PSES costs for actual indirect discharge plants are examined in detail below.

For the direct dischargers, BAT costs would require price increases of under one percent for the medium and large plants but over one percent for the small model size. Similarly, for graphite anode plants, which will incur both RCRA-ISS and BAT costs, the required price increase exceeds one percent for the small model but is under one percent for the medium and large size categories. However, the profitability decline is substantially lower than one percentage point in all cases. Also, the decrease in profitability remains close to or under ten percent. Therefore, according to EPA's closure criteria, none of the model plants is a likely closure candidate in the case of BAT costs even when RCRA-ISS costs are added for the graphite anode plants.

2.2.3 Industry Impacts

In this section, the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on chlorine manufacturers.

The model plant analysis indicates very low baseline profitability for chlorine producers, with the IRR ranging from a negative value to only 14 percent. Industry sources confirm that current profitability levels in the chlor-alkali industry are very low. There are two major factors responsible for this low-profitability situation:

- Demand growth has been less than anticipated in recent years and has failed to keep up with the capacity expansions made throughout the 1970's. The result has been excess capacity, low capacity utilization, and depressed profitability for many chlorine producers.
- Manufacturing costs have increased rapidly and have further reduced profit margins in the industry. Energy and capital costs, in particular, have risen sharply in recent years.

These factors are discussed in greater detail below.

In the early 1970's, demand for the chlorine end product polyvinyl chloride (PVC) was exceptionally strong, primarily in the housing and automobile markets. This boom in PVC demand resulted in excess demand for chlorine which spurred numerous capacity expansions. When the 1975 recession brought about large downturns in the construction and automobile industries, the demand for PVC (and chlorine) fell. Several other factors further depressed chlorine demand growth:

- Government regulation and health-related problems in such areas as fluorocarbons and chlorinated solvents eliminated or threatened to eliminate major chlorine end markets.
- Substitute competition in several end markets also contributed to declining demand for chlorine. For example, in the pulp and paper industry (representing 12 percent of total chlorine consumption), other bleaching agents are being used increasingly in place of chlorine.
- Process changes and increased efficiency in the manufacture of vinyl chloride monomer (consuming 17 percent of total chlorine production) decreased chlorine demand in these areas. One industry spokesman noted that "roughly a year's worth of growth in chlorine demand was eliminated" as a result of these developments (Chemical Week, March 14, 1979).

Thus, capacity expansions planned during earlier periods of strong demand were developed throughout the 1970's but were not matched by increased demand. Oversupply and excess capacity have resulted, and capacity utilization rates and profitability levels are currently very low.

Along with excess capacity and slower demand growth, the chlorine industry has experienced rapidly rising production costs in recent years. Energy costs, representing 40 to 60 percent of total manufacturing costs have increased significantly. Capital costs have also risen considerably. These cost increases have operated in conjunction with excess capacity and slower demand growth to obliterate chlorine producers' profit margins. As indicated by the model plant analysis, current profitability levels are very low.

The future outlook for the chlorine industry suggests the possibility of some small improvement. Two factors are particularly important:

- Further capacity expansions have been discouraged by existing low profitability levels. Therefore, demand may eventually catch up with industry capacity and result in higher utilization rates.

- Demand for a few end uses such as PVC and wastewater treatment remains strong with growth predicted by the industry at over five percent annually.

However, because production and regulatory cost increases are expected to continue, it is unlikely that chlorine producers' profitability levels will improve dramatically in the near future.

2.2.3.1 Price and Profitability Impacts

For direct dischargers, the model plant analysis indicates price increases required by effluent control costs of less than one percent for all medium and large chlorine plants. However, smaller plants would need to raise prices by 1.5 to 2.0 percent to recover effluent control costs. The costs of RCRA-ISS requirements raise price increases to 0.53 to 4.85 percent. Implementing price increases of from one to five percent in the merchant market would prove difficult given the current situation, and chlorine produced for sale would become even less profitable than it is currently. However, almost two-thirds of chlorine production is used in the manufacture of more profitable downstream products. End users of chlorine-containing products would be cushioned from the full impact of the price increase.

For example, polyvinyl chloride (PVC), a plastic used in the construction and automobile industries, requires approximately seven-tenths of a ton of chlorine for each ton of PVC manufactured. A five percent increase in the price of chlorine ($145 per ton)* would raise the cost of PVC by

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*This price does not match the price used in the price and profitability analysis becaase it reflects current (summer 1981) list prices rather than mid-1978 levels.

$5.08 per ton, or 0.25 cents per lb. Based on the current (summer 1981) list price of PVC ($0.58/lb), the price increase required to recover the higher chlorine cost is about 0.44 percent, significantly lower than the five percent price increase required per ton of chlorine.

Merchant chlorine producers currently face an oversupplied market and immediate and complete price pass-through is unlikely. However, the short-term profitability declines are slight (less than one percentage point) and therefore are not likely to result in serious impacts or plant closures for direct dischargers. Further, chlorine plants using the mercury or diaphragm cell process produce sodium hydroxide (caustic soda) as a co-product. Demand for caustic soda is currently very strong and it may be possible to at least partially recover effluent control and RCRA-ISS costs through caustic soda price increases.

The price and profitability impacts of effluent control costs on the one indirect discharger not pretreating wastewater in the chlorine subcategory are larger than those for direct dischargers. The technical contractor survey indicates that this indirect discharger corresponds to the largest diaphragm cell model plant. According to the model plant analysis, the price increase required to fully recover pretreatment costs is 2.2 percent (see Table 2-9). Again, this increase represents a very small increase in final product prices, roughly one-fourth of one percent of current PVC prices. Thus, full price pass-through is likely. Even if full pass-through is not possible, the plant would experience only a small decline in profitability, 0.4 percentage points in IRR or roughly four percent of the baseline profitability level (see Table 2-11a).

Therefore, plant closure is not expected for the indirect discharger in the subcategory. These observations suggest that chlorine plant closures are unlikely.

2.2.3.2 Other Impacts and Conclusion

The additional costs of effluent control and RCRA-ISS requirements should not represent a major problem for the chlor-alkali subcategory. While price increases required to recover combined effluent control and RCRA-ISS costs exceed one percent for small and medium plants, chlorine producers should be able to pass through their cost increases in final product prices. The final product prices would require less than a one percent increase to fully recover effluent control and RCRA-ISS costs.

If cost pass-through is not immediate and complete, resulting profitability impacts are not expected to result in plant closures, with profitability declines of less than one percentage point for the affected plants in the industry. Therefore, no plant closures or other secondary impacts (employment, supply, etc.) are expected to result from the costs of effluent control and RCRA-ISS regulations.

3. CHROME PIGMENTS

3.1 CHARACTERIZATION

Five chrome colors make up the product group known as chrome pigments. These five products serve a variety of functions. For example, chrome yellows offer brilliant color and excellent light fastness, characteristics which make them useful as traffic line paints. Chrome oxide green is an excellent coloring agent for cement and ceramic products due to its strong resistance to alkalies, acids, and high temperatures. Figure 3-1 presents the sources and uses of chrome pigments.

Presently the chrome pigments industry faces serious pollution control problems at both the end market and production levels. OSHA regulations call for a reduction in lead and chromium dust levels to 50 micrograms per cubic meter of air in both end market workshops (i.e., paint manufacturing plants) and pigment production facilities. The status of these standards is uncertain, and this will affect the conclusions of this analysis. In addition, producers will face strict limits on the discharge of hexavalent chromium, a known carcinogen, from production facilities.

3.1.1 Demand

The five pigments forming the chrome pigments product group have widely differing characteristics and end uses. The particular nature of each product and its end markets are discussed separately below.

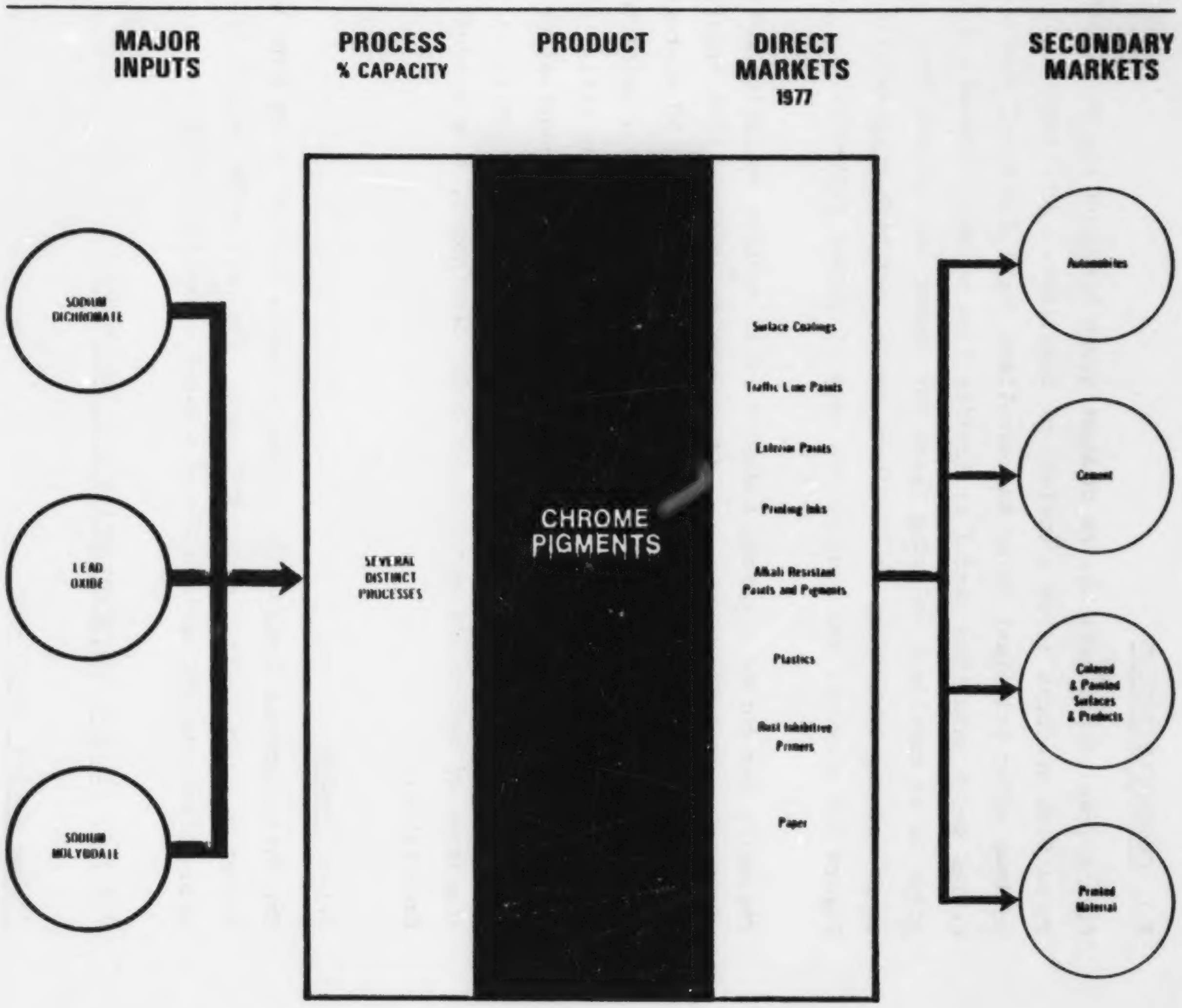
3.1.1.1 Pigment Characteristics and End Markets

Chrome Yellow and Orange

Chrome yellows and oranges derive their color and physical characteristics from lead chromate. The medium yellow hues are formed from

FIGURE 3-1

CHROME PIGMENTS:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
SODIUM DICHROMATE
LEAD OXIDE
SODIUM MOLYBDATE
SEVERAL DISTINCT PROCESSES
CHROME PIGMENTS
Surface Coatings
Traffic Line Paints
Exterior Paints
Printing Inks
Alkali Resistant Paints and Pigments
Plastics
Rust Inhibitive Primers
Paper
Automobiles
Cement
Colored & Painted Surfaces & Products
Printed Material

normal lead chromate ($PbCrO_4$); the redder shades and oranges, from basic lead chromate ($PbO \cdot PbCrO_4$).

Chrome yellows are bright, opaque, and light fast. Their largest application is as a coloring agent for traffic line paints. They also are used in many other paint applications, as well as printing inks, plastics, paper, and floor coverings. A substantial amount of chrome yellow is combined with iron blues to form chrome green. The uses of chrome oranges are very similar to those of chrome yellows. In addition, the darker shades are used in rust inhibitive paints and primers for ferrous metals.

Zero growth, or, more likely, a fall in demand, is projected for chrome yellows and oranges. The primary reason is the increasing severity of OSHA regulations concerning worker exposure to airborne lead and chromium. Regulations have been issued requiring end users of chrome pigments (e.g., paint manufacturers) to limit both airborn lead and chromium to 50 micrograms per cubic meter of air. Current regulations call for producers of chrome pigments to limit lead dust levels to 200 micrograms per cubic meter, with the limit falling to 50 micrograms per cubic meter of air within five years. Producers of chrome pigments currently must limit chromium dust levels to 50 micrograms per cubic meter of air. Both producers and consumers of lead chromates anticipate that the cost of implementing these regulations will force a switch in demand away from chrome pigments toward organic substitutes. The standards will increase substantially the cost of producing lead chromates, as well as the cost of using them.

Chrome Green

Chrome green is a mixture of chrome yellow and iron blue. Shades of chrome green run from light to very dark. Chrome green is used in paints, enamels, inks, oil cloth, and paper.

As a mixture of chrome yellow and iron blue, chrome green is subject to many of the health problems which currently face chrome yellow. The costs associated with limiting worker exposure to lead and chromium dusts could be particularly injurious to this product, as it has a very competitive substitute in the organic color Thalo-Green.

Chrome Oxide Green

There are two chrome oxide greens - anhydrous and hydrated. The anhydrous product is resistent to alkali, acid, and high temperatures, and exhibits excellent light fastness. These attributes make it valuable for use in alkaline environments such as portland cement, ceramic tile glazes, rubber, certain printing inks, and concrete and bridge paints. Anhydrous chromic acid (metallurgical grade) is used in the manufacture of chromium metal and aluminum-chromium master alloys.

Hydrated chrome oxide green is much more brilliant than the anhydrous product. It also is much less resistant to alkali. It gives a brilliant, bluish-green transparent finish, and is widely used in automobile paints.

Chrome oxide green does not face a lead exposure problem. However, as with all chrome pigments, there is some concern over the discharge of hexavalent chromium, a known carcinogen. Demand for this pigment is expected to increase at the same rate as the GNP.

Molybdate Chrome Orange

The molybdenum oranges are a physical mixture of lead chromate, lead molybdate, and lead sulfate. As a group, these pigments are very strong and brilliant, and have excellent tinting strength. Although they cost more than chrome oranges, they are cost effective in many applications due to their exceptional strength. They are used in many paints, enamels, and laquers, as well as floor coverings and printing inks. These lead-containing pigments also face declining demand due to OSHA regulations.

Zinc Yellow

Zinc yellow is a complex of zinc, potassium, and chromium compounds. Zinc yellow has limited water solubility which restricts its use as a pigment. The same quality, however, makes it a useful corrosion inhibitive pigment for prime coating metals. It has particularly strong applications for prime coating nonferrous metals such as aluminum and magnesium.

Zinc yellow has some applications in decorative finishing. However, it is used most frequently with other colors such as hydrated chrome oxide green, because, used alone, it weathers to a dull greenish finish. Zinc yellow also is used to make zinc green pigment.

Demand for this pigment should continue to grow with the expansion of the GNP. Its end markets generally are mature, and it does not face the serious lead pollution problems experienced by chrome yellow, chrome green, and molybdate chrome orange.

3.1.1.2 Demand Summary

Predictions for demand growth in the chrome pigments industry range from zero growth, at best, to a substantial decline in demand. Health issues concerning exposure to lead and chromium are an important factor in this prediction.

Chrome yellows and oranges and molybdate chrome oranges comprise approximately 75 percent of the chrome pigments market. These two products, as well as chrome green, contain substantial amounts of lead, which is coming under increasingly strict OSHA regulations on worker exposure. These regulations could cause a switch to organic colors in many applications. Lead chromates are expected to remain strong in areas such as traffic marking paints and water flexographic inks for printing cartons where their durability and light fastness make them especially suitable.

However, they are expected to continue losing market share in areas where consumer contact with lead-containing pigments is high. They have already lost a great deal of the trade sale paint and publishing ink markets, where it is feared that children will be exposed to excessive lead through ingestion of paint chips and printed material. Auto makers have attempted to replace chrome colors with other pigments, but as yet have been unable to find suitable substitutes.

Zinc yellow and chrome oxide green contain no lead and are, therefore, subject to fewer environmental and health constraints. However, they must still meet the 50 microgram per cubic meter of air chromium dust standard. In the long run, these two pigments should grow at approximately the rate of GNP growth. However, their growth may vary widely with economic fluctuations.

The outlook for chrome pigments can be summarized as follows:

- The impacts of OSHA regulations are uncertain. However, these regulations, particularly those concerning lead-containing dusts, will raise the price of chrome colors and make them more difficult and expensive to use in manufacturing other products. This will cause some substitution with organic colors. The pigments most severely affected will be chrome yellow and orange, molybdate chrome orange, and chrome green.
- Chrome oxide green and zinc yellow contain no lead, and should continue moderate growth. However, these pigments constitute such a small fraction of total chrome pigments production that their growth will be insufficient to prevent declining industry-wide demand.

3.1.2 Supply

3.1.2.1 Production

For the period 1969 to 1979, production statistics for chrome pigments are available for only three of the five pigments being studied. Partial statistics are available for chrome green and zinc yellow, but have been withheld during some years to avoid disclosing information concerning any individual firms.

From 1968 to 1979, production of chrome yellow and orange, which represents approximately 50 percent of chrome pigments production, rose at an annual rate of only 0.46 percent. Molybdate chrome orange, which represents 25 percent of total chrome pigments production, rose at an annual rate of 2.4 percent. During the years for which data are available (see Table 3-1), production of chrome green fell at a 1.4 percent annual rate, while zinc yellow production fell at an annual rate of 3.6 percent. The slow growth rate of chrome pigments in general is an indication of the maturity of the industry. Table 3-1 and Graphs 3-1 to 3-3 summarize production levels and prices during the period 1968 to 1979.

3.1.2.2 Producers

There are currently 12 producers of chrome pigments, 10 of which produce chrome yellow and orange. Molybdate chrome orange is manufactured by seven firms. Two producers, Minnesota Mining and Manufacturing and Pfizer, manufacture only chrome oxide green. Chrome green is produced only by Ciba-Geigy* and zinc yellow is manufactured by two companies, DuPont and Borden. Statistics on plant capacities were unavailable for chrome pigment producers. A summary of chrome pigments producers is provided in Table 3-2.

The two largest producers are Ciba-Geigy and DuPont, followed by Harshaw Chemical Company. American Cyanamid, previously one of the four largest producers of chrome pigments, shut down its chrome pigments plant in late 1978. DuPont is the only producer integrated forward to end products (DuPont is a major paint producer). No firms are integrated backward to sodium dichromate, which is a major input in chrome pigments production.

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* Formerly Hercules Chemical, Inc.

TABLE 3-1

CHROME PIGMENTS PRODUCTION

COLOR	YEAR	ANNUAL PRODUCTION (short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
Chrome Green	1968	2,828		950	
	1969	2,619	-7.4	928	-2.3
	1970	2,552	-2.6	860	-7.3
	1971	2,707	6.1	965	12.2
	1972	NA		NA	
	1973	NA		NA	
	1974	NA		NA	
	1975	NA		NA	
	1976	NA		NA	
	1977	NA		NA	
	1978	NA		NA	
	1979	NA		NA	
Chrome Oxide Green	1968	6,232		956	
	1969	5,862	-5.9	952	-0.4
	1970	6,751	15.2	954	0.2
	1971	6,584	-2.5	980	2.7
	1972	6,155	-6.5	1,011	3.2
	1973	7,159	16.3	1,054	4.3
	1974	7,676	7.2	1,402	33.0
	1975	5,608	-26.9	1,759	25.5
	1976	6,140	9.5	1,862	5.9
	1977	8,796	43.3	1,894	1.7
	1978	12,321	40.1	2,332	23.1
	1979	11,459	-7.0	2,678	14.8
Chrome Yellow and Orange	1968	32,789		704	
	1969	32,001	-2.4	710	0.9
	1970	32,449	1.4	753	6.1
	1971	29,027	-10.5	780	3.6
	1972	33,770	16.3	764	-2.1
	1973	37,263	10.3	755	-1.2
	1974	37,942	1.8	1,104	46.2
	1975	26,091	-31.2	1,259	14.0
	1976	35,335	35.4	1,361	8.1
	1977	35,207	- .4	1,530	12.4
	1978	37,028	5.2	1,665	8.8
	1979	34,473	-6.9	1,921	15.4

TABLE 3-1

CHROME PIGMENTS PRODUCTION (Continued)

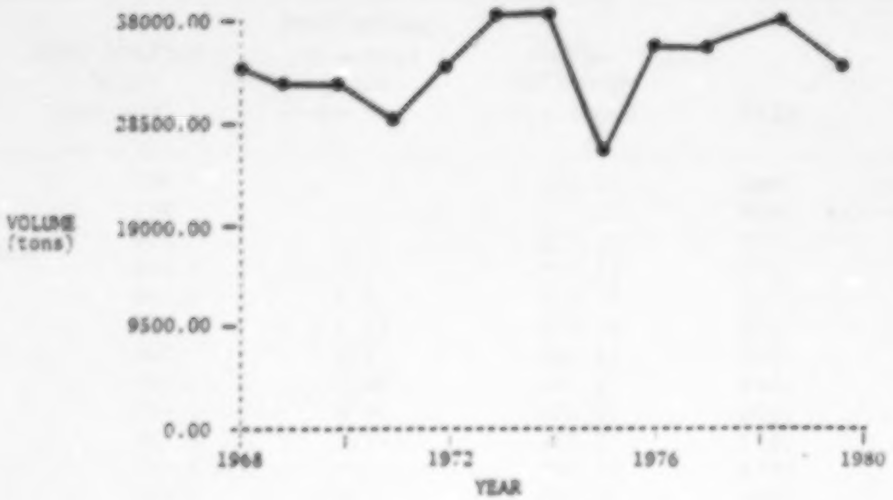
COLOR	YEAR	ANNUAL PRODUCTION (short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
Molybdate Chrome Orange	1968	11,375		957	
	1969	11,373		963	0.6
	1970	11,025	-3.1	998	3.6
	1971	11,375	3.2	1,043	4.5
	1972	12,410	9.1	1,120	7.3
	1973	14,057	13.3	1,166	4.1
	1974	14,586	3.8	1,504	29.0
	1975	9,559	-34.5	1,720	14.4
	1976	16,883	76.6	1,903	10.6
	1977	13,976	-17.2	2,134	12.1
	1978	14,403	3.1	2,192	2.7
	1979	14,819	2.9	2,694	22.9
Zinc Yellow	1968	7,408		613	
	1969	7,291	-1.6	655	6.9
	1970	5,750	-21.1	657	0.3
	1971	5,586	-2.9	700	6.5
	1972	5,657	1.3	766	9.4
	1973	5,307	-6.2	880	14.9
	1974	5,756	8.5	1,178	33.9
	1975	NA		NA	
	1976	NA		NA	
	1977	NA		1,326	
	1978	NA		NA	
	1979	3,916		1,994	

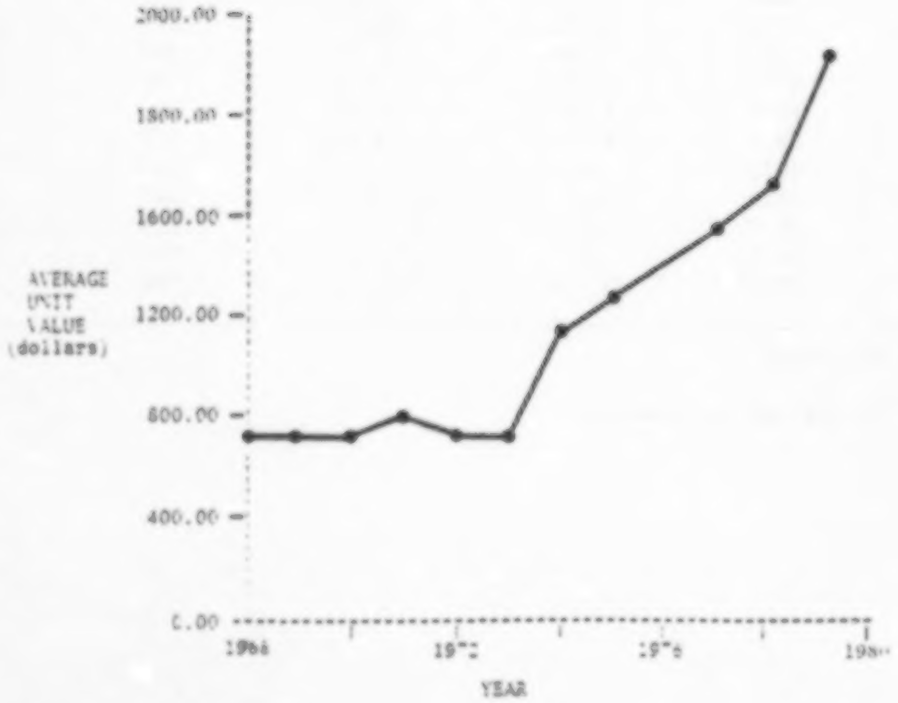
NA = Not Available

SOURCE: Department of Commerce

GRAPH 3-1

CHROME YELLOW AND ORANGE PRODUCTION AND PRICE





SOURCE: Department of Commerce

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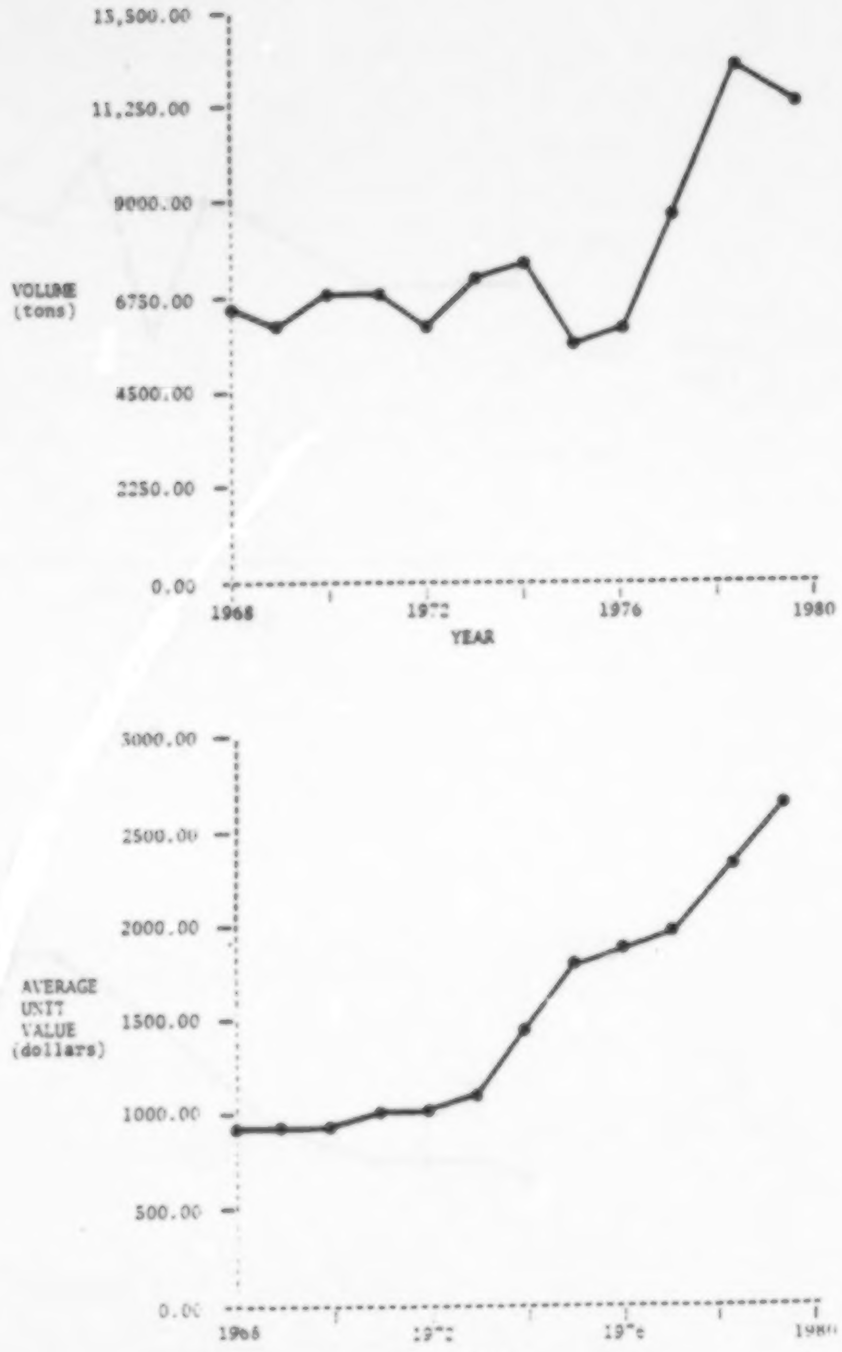
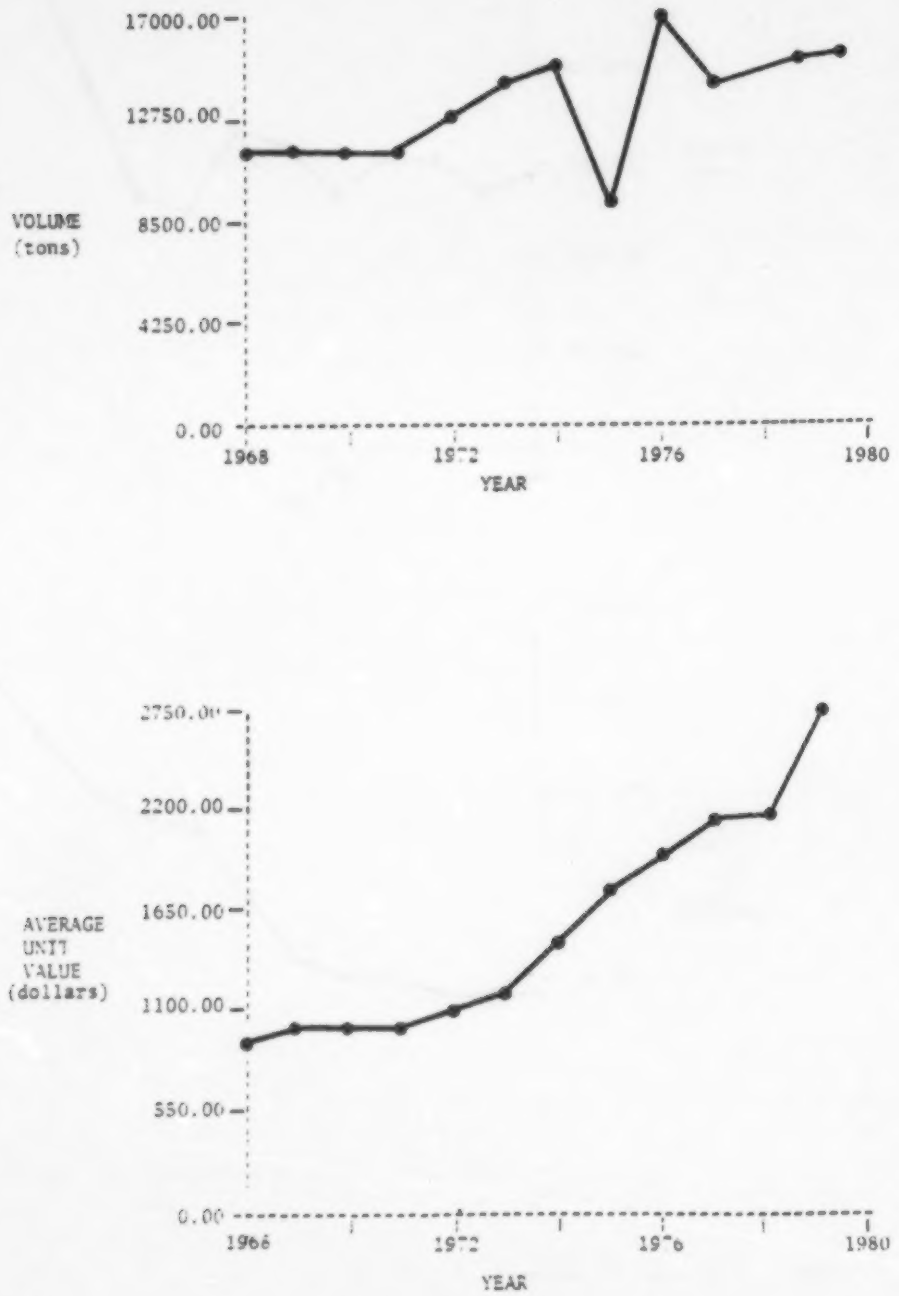
GRAPH 3-2
CHROME OXIDE GREEN PRODUCTION AND PRICE



SOURCE: Department of Commerce

GRAPH 3-3
MOLYBDATE CHROME ORANGE PRODUCTION AND PRICE



SOURCE: Department of Commerce

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TABLE 3-2

PRODUCERS OF CHROME PIGMENTS[1]

PRODUCER	LOCATION	CHROME GREEN	CHROME OXIDE GREEN	CHROME YELLOW & ORANGE	MOLYBDATE CHROME ORANGE	ZINC YELLOW
American Cyanamid[2]	Willow Island W.VA			X	X	X
Borden, Inc.	Cincinnati OH			X	X	X
DuPont	Newark NJ			X	X	X
Harshaw Chemicals	Louisville KY			X	X	
Ciba-Geigy[3]	Glens Falls NY	X	X	X	X	
Kikuchi Color & Chemical	Paterson NJ			X		
Mineral Pigments Corp.	Muirkirk MD			X		
Minnesota Mining & Manufacturing	Copley OH		X			
Nichem, Int.[4]	Chicago IL			X		
Pfizer	Lehigh Gap PA		X			

TABLE 3-2

PRODUCERS OF CHROME PIGMENTS 1/
(Continued)

PRODUCER	LOCATION	CHROME GREEN	CHROME OXIDE GREEN	CHROME YELLOW & ORANGE	MOLYBDATE CHROME ORANGE	ZINC YELLOW
Reichhold Chemicals	Brooklyn NY			X	X	
Sterling Drug (Hilton Davis)	Cincinnati OH			X	X	
Wayne Chemicals	Milwaukee WI			X	X	

3
1/ Plant capacities were unavailable.
2/ This plant discontinued chrome pigments production in late 1979.
3/ Formerly Hercules Chemical, Inc.
4/ Chrome pigments production is less than 500 tons per year.

SOURCE: Industry Sources

3.1.2.3 Process

The manufacturing processes for chrome pigments have several steps in common, and the various pigments often are produced either simultaneously or sequentially in the same facility. Sodium dichromate serves as a source of chromium for all of the pigments. Several of the pigments also contain substantial amounts of lead. Table 3-3 shows the primary constituents of each pigment.

Chrome yellow and orange represent over 50 percent of all chrome pigments manufactured, and serve as an input in producing other pigments. Chrome yellow has, therefore, been chosen as the typical chrome pigment, and its manufacturing process will be examined more extensively.

Chrome yellow is a physical mixture of lead chromate, lead sulfate, and, occasionally, zinc sulfate. The pigment is primarily lead chromate, which constitutes approximately 93 percent of the product.

The general reaction for producing lead chromate from litharge (lead oxide), nitric acid, and sodium dichromate, is as follows:

$$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$$

$$2Pb(NO_3)_2 + H_2O + Na_2Cr_2O_7 \rightarrow 2PbCrO_4 + 2NaNO_3 + 2HNO_3$$

Following the reaction, chrome yellow is precipitated, washed, filtered, and dried. The product can be packaged for commercial use, or mixed with iron blues to form chrome green.

Between 82.5 and 88.0 percent of chrome pigments manufacturing costs are due to raw materials. The remainder of the costs are shared almost equally by utility, labor and maintenance, and overhead. (Table 3-4 provides estimates of raw material requirements and manufacturing costs for chrome yellow pigment.)

TABLE 3-3

CONSTITUENTS OF CHROME PIGMENTS

PIGMENT	CHEMICAL CONSTITUENTS
Chrome Yellow and Orange	Lead Chromate with Impurities of Lead Sulfate and Zinc Sulfate
Chrome Green	Physical Mixture of Chrome Yellow (Lead Chromate) and Iron Blue (Ferric Ferrocyanide)
Chrome Oxide Green and Guinet's Green (Hydrated Chromic Oxide)	Anhydrous and Hydrated Chromic Oxide
Molybdate Chrome Orange	Mixture of Lead Chromate, Lead Sulfate, and Lead Molybdate
Zinc Yellow	Complex Material Containing Compounds of Zinc, Potassium, and Chromium.

SOURCE: U.S. EPA, Development Document, May 1975

TABLE 3-4a

ESTIMATED COST OF MANUFACTURING CHROME YELLOW PIGMENT*
(Mid-1978 Dollars)

Plant Capacity	2,100 tons/year
Annual Production	1,650 tons/year (78% capacity utilization)
Fixed Investment	$1.4 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Lead Oxide	1429 lb	.596	851.70
- Nitric Acid	80 lb	.110	8.80
- Sodium Hydroxide (50%)	265 lb	.080	21.20
- Sodium Dichromate	980 lb	.300	294.00
- Sulfuric Acid	20 lb	.016	.30
- Calcium Hydroxide	25 lb	.016	.40
• Utilities			
- Power	150 kWh	.03	4.50
- Fuel	25 10^6 Btu	2.50	62.50
- Process Water	9 kgal	.75	6.80
- Cooling Water	1.8 kgal	.10	.20
Total Variable Costs			$1,250.40
SEMI-VARIABLE COSTS			
• Labor			158.00
• Maintenance			33.90
Total Semi-Variable Costs			$191.90
FIXED COSTS			
• Plant Overhead			59.20
• Depreciation			84.70
• Taxes & Insurance			17.00
Total Fixed Costs			$160.90
TOTAL COST OF MANUFACTURE			$1,603.20

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 3-4b

ESTIMATED COST OF MANUFACTURING CHROME YELLOW PIGMENT*

(Mid-1978 Dollars)

Plant Capacity	5,600 tons/year
Annual Production	4,400 tons/year (78% capacity utilization)
Fixed Investment	$2.7 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Lead Oxide	1429 lb	.596	851.70
- Nitric Acid	80 lb	.110	8.80
- Sodium Hydroxide (50%)	265 lb	.080	21.20
- Sodium Dichromate	980 lb	.300	294.00
- Sulfuric Acid	20 lb	.016	.30
- Calcium Hydroxide	25 lb	.016	.40
• Utilities			
- Power	150 kWh	.03	4.50
- Fuel	25 10^6 Btu	2.50	62.50
- Process Water	9 kgal	.75	6.80
- Cooling Water	1.8 kgal	.10	.20
Total Variable Costs			$1,250.40
SEMI-VARIABLE COSTS			
• Labor			125.00
• Maintenance			24.50
Total Semi-Variable Costs			$149.50
FIXED COSTS			
• Plant Overhead			31.20
• Depreciation			61.20
• Taxes & Insurance			12.20
Total Fixed Costs			$104.60
TOTAL COST OF MANUFACTURE			$1,504.50

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 3-4c

ESTIMATED COST OF MANUFACTURING CHROME YELLOW PIGMENT*
(Mid-1978 Dollars)

Plant Capacity	8,500 tons/year
Annual Production	6,600 tons/year (78% capacity utilization)
Fixed Investment	$3.6 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Lead Oxide	1429 lb	.596	851.70
- Nitric Acid	80 lb	.110	8.80
- Sodium Hydroxide (50%)	265 lb	.080	21.20
- Sodium Dichromate	980 lb	.300	294.00
- Sulfuric Acid	20 lb	.016	.30
- Calcium Hydroxide	25 lb	.016	.40
• Utilities			
- Power	150 kWh	.03	4.50
- Fuel	25 10^6 Btu	2.50	62.50
- Process Water	9 kgal	.75	6.80
- Cooling Water	1.8 kgal	.10	.20
Total Variable Costs			$1,250.40
SEMI-VARIABLE COSTS			
• Labor			97.70
• Maintenance			21.80
Total Semi-Variable Costs			$119.50
FIXED COSTS			
• Plant Overhead			24.40
• Depreciation			54.40
• Taxes & Insurance			10.90
Total Fixed Costs			$ 89.70
TOTAL COST OF MANUFACTURE			$1,459.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 3-4d

ESTIMATED COST OF MANUFACTURING CHROME YELLOW PIGMENT*
(Mid-1978 Dollars)

Plant Capacity	25,400 tons/year
Annual Production	19,800 tons/year (78% capacity utilization)
Fixed Investment	$7.3 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Lead Oxide	1429 lb	.596	851.70
- Nitric Acid	80 lb	.110	8.80
- Sodium Hydroxide (50%)	265 lb	.080	21.20
- Sodium Dichromate	980 lb	.300	294.00
- Sulfuric Acid	20 lb	.016	.30
- Calcium Hydroxide	25 lb	.016	.40
• Utilities			
- Power	150 kWh	.03	4.50
- Fuel	25 10^6 Btu	2.50	62.50
- Process Water	9 kgal	.75	6.80
- Cooling Water	1.8 kgal	.10	.20
Total Variable Costs			$1,250.40
SEMI-VARIABLE COSTS			
• Labor			27.30
• Maintenance			14.70
Total Semi-Variable Costs			$ 42.00
FIXED COSTS			
• Plant Overhead			6.80
• Depreciation			36.80
• Taxes & Insurance			7.40
Total Fixed Costs			$ 51.00
TOTAL COST OF MANUFACTURE			$1,343.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

3.1.3 Competition

There are three principal forms of competition in the pigments market: substitute competition, import competition, and competition among producers. The main substitutes for chrome pigments are organic colors. Organics are substantially more expensive than chrome colors and are difficult to work into some manufacturing systems. In addition, they are less desirable and light fast than chrome pigments. However, if the costs of pollution control and worker safety significantly raise the price of chrome pigments, organic colors will become more competitive. Increasing concern over the adverse health effects of chrome pigments at the manufacturing and consuming level also could lead to a switch away from chrome pigments. Retail paint customers switched away from chrome pigments in the early 1970's largely due to the fear that ingestion of paints by children would lead to severe health problems.

Imports have become less of a factor in the pigments market since 1972. From 1972 to 1979, the market share held by imports fell from 16 percent to approximately eight percent. However, imports continue to be significant as constraints on domestic price increases. Major sources of imports include West Germany, Canada, Japan, Great Britain, Poland, and Norway. Producers in these countries have more modern plant facilities and, therefore, face fewer environmental problems than U.S. chrome pigments manufacturers. As a result, foreign producers enjoy a cost advantage. While imports have decreased since 1972 due to increased ocean shipping rates and the declining value of the dollar, the worker safety and pollution control costs incurred by domestic chrome pigments producers, combined with foreign producers existing cost advantage, may make imports more competitive in the U.S. market over the next five years.

Competition among domestic producers of chrome pigments can be separated into two segments. The first segment is the merchant market for pigments. While consumers of chrome pigments are relatively sensitive to price and supplier-customer relationships are not always stable, producers have tended to keep their prices close to one another in this segment of the market.

The second, and more competitive segment of the chrome pigments industry is the market for traffic yellow pigments. These pigments are sold by competitive bid to local and state governments for use in traffic marking paints. Volumes sold in this market are so large that producers are willing to discount from list prices, and bidding becomes very competitive. Producers can afford to discount somewhat, as pigments for traffic paints do not have to be of the same quality as those for other applications.

3.1.4 Economic Outlook

3.1.4.1 Revenue

Total revenue is the product of quantity sold and average unit price. Although these two variables are discussed separately, they are interrelated.

3.1.4.1.1 Quantity

The outlook for domestic production of chrome pigments indicates zero growth at best, or, more likely, a decline in production. There are several reasons for this outlook:

- The markets for chrome pigments are mature and offer few possibilities for significant growth. Sales have been constant for the last several years.

- Regulations concerning worker exposure to lead- and chromium-containing pigment dust at both the pigment production and utilization levels threaten to raise the costs of the raw pigment and its ultimate end products. This will lead to some loss of market share.

- The health issues associated with chrome pigments may persuade manufacturers to use substitute products, regardless of the cost advantages and desirable qualities of the pigments. Trade sale paint manufacturers and printers already have switched away from chromes to some degree, and automakers have expressed some interest in substitute pigments.

3.1.4.1.2 Price

Approximately 85 percent of chrome pigments manufacturing costs are due to raw materials. Among the principal raw material inputs in chrome pigments production are lead oxide and sodium dichromate. The price of lead oxide has been rising fairly rapidly, with the price of dichromate rising at a more moderate pace. According to an industry source, passing through raw material cost increases should pose little problem, as chrome pigments are substantially less expensive than their major substitute--organic colors (approximately \$1/lb vs. \$4/lb). In addition, no domestic producers are integrated vertically to raw materials, and, thus, no producer should have a substantial cost advantage which would allow them to restrain prices. Foreign producers also should experience cost increases similar to those faced by domestic manufacturers.

3.1.4.2 Manufacturing Costs

As mentioned previously, raw materials account for 82.5 to 88.0 percent of chrome pigments manufacturing costs. The price of lead oxide, a principal input, has been increasing rapidly. Sodium dichromate, another major input, has experienced more moderate price increases. Sodium molybdate, a major input in molybdate chrome orange, also has experienced rapidly increasing prices. Raw material costs are expected to continue increasing at a moderate pace.

The remaining 12.0 to 17.5 percent of manufacturing costs are shared almost equally by utilities, labor and maintenance, and plant overhead. These costs should grow at a moderate pace, except for energy, which may grow more rapidly.

3.1.4.3 Profit Margins

Moderate cost increases are expected in manufacturing chrome pigments, primarily due to increased raw material costs. It is anticipated that producers will be able to pass this cost through as price increases, based on recent history and manufacturers' comments.

Producers fear, however, that they may be unable to pass along the increased costs of lowering pigment dust levels in the workplace to the OSHA standard of 50 micrograms per cubic meter of air. If they were unable to pass along these costs, profit margins could be eroded significantly.

3.1.5 Characterization Summary

Five pigments form the chrome pigments product group. The pigments are used in a variety of applications such as paints, plastics, printing inks, alkali-resistant paints and dyes, and rust inhibitive primers. Chrome pigments offer several advantages: they are bright, opaque, cost effective, and light fast. Some of the pigments offer additional advantages: chrome oxide green is an excellent alkali-resistant pigment; zinc yellow is a useful rust inhibitor.

The chrome pigments subcategory faces serious problems in meeting OSHA regulations concerning worker exposure to lead and chromium dusts. Current regulations call for a reduction of both lead and chromium dust levels to 50 micrograms per cubic meter of air. These regulations apply to chrome pigment production facilities as well as facilities using the pigments to manufacture other products. The status of OSHA regulations is uncertain. However, both manufacturers and consumers of chrome pigments indicate that these regulations may force a switch away from chrome pigments toward organic substitutes. Chrome yellow and orange, molybdate chrome orange, and chrome green will be affected most severely as they face lead as well as chromium regulations. Zinc yellow and chrome oxide green contain no lead.

Chrome pigments are manufactured by 12 firms in the U.S. Ten firms produce chrome yellow and orange, and several firms produce one or more of the remaining four pigments. None of the manufacturers are integrated vertically to inputs. DuPont is the only producer integrated forward to end products (DuPont is a major producer of paints).

Historically, chrome pigments producers have been able to pass increased raw materials costs through to consumers. However, they may be unable to pass through the increased expenditures required to meet OSHA regulations on airborne pigment dust. This could lower profitability, as well as force consumers to switch away from chrome colors to organic substitutes.

3.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the chrome pigments subcategory to comply with BAT and PSES effluent control standards. The technical contractor has designed and estimated the cost of effluent control technologies which can be used to achieve these standards. For this subcategory, BAT and PSES limitations are based on BPT and, therefore, the effluent control costs for direct and indirect dischargers are equivalent. The technical contractor's cost estimates are used to make an assessment of the economic impacts that effluent control costs will have on the subcategory.

In some of the other subcategories studied in this report, base level (i.e., BPT) treatment technologies are in place. However, this is not the case in the chrome pigments subcategory because:

- The eight plants which discharge to municipal treatment systems have never been subject to regulations.
- Data gathered by the technical contractor and EPA show that only two plants have control equipment in place.

This analysis will address the impact of effluent control costs required for compliance with BAT and PSES regulations. The final regulations provide an exemption for small indirect dischargers (discharging less than 55 million gallons annually).* The basis for the exemption is the severe economic effects associated with compliance costs for these plants (see Appendix E).

Since the chrome pigments subcategory will be affected by the Resource Conservation and Recovery Act (RCRA), the impacts of the combined costs of compliance with PSES/BAT and RCRA's Interim Status Standards (ISS) are also examined. These costs are not applicable to the small plants which are exempt from categorical PSES removal since, without the pre-treatment equipment in place, they produce no hazardous sludge.

3.2.1 Pollution Control Technology and Costs

Capital and operating pollution control costs estimates have been developed by the technical contractor for the effluent control technology required to meet PSES/BAT levels of waste removal.

Sources of wastewater from chrome pigments production include filtrates, pigment particulate wastes, and effluent from air pollution control. Major pollutants include suspended solids, soluble and insoluble chromate salts and other metals, such as lead and zinc. The pollution control process is summarized below:

- Wastewater is collected in a holding tank where sulfuric acid is added for pH adjustment.
- Sulfur dioxide is added to the wastewater to reduce hexavalent chromiumn to non-toxic trivalent chromium.
- Caustic soda is added to the wastewater to raise the pH and precipitate the chromium.

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*This level of flow corresponds to a production rate of 2,000 metric tons (2,200 short tons) of chrome pigment annually.

- Overflow is filtered and discharged; underflow passes through a filter press and then to a holding pond; solids are landfilled.

Pollution control costs were estimated for four model plants assumed to be complex continuous process pigment facilities. Model plant production rates are 1,650, 4,400, 6,600, and 19,800 tons per year. For the model plants, an average wastewater unit flow rate of 105 m^3/kkg was used. Effluent control costs for the model plants are summarized in Table 3-5. The table also includes the costs of compliance with RCRA-ISS requirements.

Estimates of chrome yellow manufacturing costs for the four model plants are \$1,603.20, \$1,504.50, \$1,459.60, and \$1,343.40 per ton of product. These cost estimates are based on estimates developed by an economic subcontractor (see Table 3-4); pollution control costs are not included in these estimates. Table 3-6 summarizes the model plant financial parameters used in the analysis.

The capital and annual costs required for compliance with BAT/PSES and RCRA-ISS by the chrome pigments subcategory are summarized in Table 3-7. These costs are based on the model plant pollution control costs and current industry production levels. Two direct dischargers have BAT removal technology in place. Three small indirect dischargers incur no PSES or RCRA costs based on the exemption.

The additional costs required for subcategory compliance with BAT removal are estimated to be about \$0.8 million; subcategory compliance with categorical PSES removal would require additional annual costs of about \$4.9 million. Therefore, the total subcategory cost for effluent limitations is estimated at \$5.7 million. RCRA requirements would add another \$0.6 million to yield a total annualized subcategory compliance cost of \$6.3 million.

Note that the RCRA costs are for disposal of all plant-produced hazardous wastes, not just the incremental waste resulting from the use of

TABLE 3-5: POLLUTION CONTROL COSTS

Chemical: Chrome Pigments

	PSES/BAT		RCRA-ISS			
Model Plant Production (tons/year)	Capital Investment	Annual Operating Cost	Capital Investment*	Initial Cost	Annual Operating Cost	Total Closure Fund*
1,650	$518,477	$259,302	0	$5,135	$33,738	0
4,400	900,334	414,343	0	3,423	36,147	0
6,600	1,164,466	528,681	0	3,423	70,284	0
19,800	2,631,692	1,190,320	0	3,423	136,850	0

*It is assumed that all chrome pigment plants will dispose of their wastes in an off-site landfill; therefore, there are no capital or closure fund costs required for compliance with RCRA-ISS.

SOURCE: Technical Contractor

TABLE 3-6: MANUFACTURING COSTS

Chemical: Chrome Pigments

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs Per Ton
1,650	1,400,000	$1,603.20
4,400	2,700,000	1,504.50
6,600	3,000,000	1,459.60
19,800	7,300,000	1,343.40

Note: All costs are in mid-1978 dollars.

Table 3-7

SUBCATEGORY COMPLIANCE COSTS

Chemical: Chrome Pigments

	PSES			BAT			BAT/PSES Plus RCRA-ISS		
Model Plant Production (Tons/Year)	Estimated Annual Production by Affected Plants (Tons)	Investment Costs	Annualized Costs ($/Year)	Estimated Annual Production by Affected Plants (Tons)	Investment Costs	Annualized Costs ($/Year)	Estimated Annual Production by Affected Plants (Tons)	Investment Costs	Annualized Costs ($/Year)
1,650	2,000	518,477	451,300	1,000	518,477	225,650	3,000	1,036,954	740,888
4,400	4,000	900,334	555,120	4,000	900,334	555,120	8,000	1,800,668	1,177,692
6,600	18,000	2,328,932	2,134,080	0	NA	NA	18,000	2,328,932	2,328,359
19,800	20,000	2,631,692	1,782,000	0	NA	NA	37,500	2,631,692	2,042,988
TOTAL	44,000	6,379,435	4,922,500	5,000	1,418,811	780,770	66,500	7,798,246	6,289,927

NA: Not Applicable

NOTE: All costs are in mid-1978 dollars.

BAT/PSES controls. Therefore, the analysis overstates the incremental RCRA costs which would result from the imposition of BAT/PSES.

3.2.2 Model Plant Analysis

This section outlines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

- Price Rise - the calculation of the price increase required to fully recover the increased pollution control costs.
- Profitability Decline - the maximum decline in profitability that would result if no price increase were possible.
- Price Elasticity of Demand - a subjective estimate based on information developed in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.
- The Capital Ratio - the ratio of pollution control capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

3.2.2.1 Price Rise Analysis

The price rise analysis assumes full pass-through of all pollution control costs. Table 3-8 summarizes the price rise calculation for the model plants. The price increase required to fully recover the costs of BAT/PSES control levels ranges from 5.5 to 14.0 percent. The price increases required to recover both RCRA-ISS and BAT costs are slightly higher, ranging from 6.0 to 15.4 percent.

3.2.2.2 Profitability Analysis

The profitability analysis assumes no price pass-through and examines the resulting decline in the return on investment (ROI) and the internal

TABLE 3-8

PERCENTAGE PRICE RISE

Chemical: Chrome Pigments

Price: $1605/ton

Model Plant Production (tons/year)	BAT/PSES*	BAT/PSES* plus RCRA-ISS
1,650	14.03%	15.36%
4,400	8.63	9.15
6,600	7.37	8.04
19,800	5.54	5.97

* For this subcategory, BAT and PSES costs are equivalent.

rate of return (IRR). The profitability impacts of BAT/PSES removal costs are large for all four model plants. The ROI declines by approximately 18 to 19 percentage points for the smallest and largest plants and by over 11 percentage points for the two intermediate model plants. These declines represent 36 to over 100 percent of baseline profitability. Application of BAT/PSES technology reduces the IRR by 9 to 12 percentage points for the three largest model plants (see Table 3-9a), or by 26 to 57 percent of baseline profitability.

The incremental costs of RCRA-ISS increase the profitability declines slightly over the profitability impacts of BAT/PSES removal costs. The ROI declines by 12.3 to 20.9 percentage points or 38 to over 100 percent of the baseline profitability, depending on model size. The IRR falls by 10.8 to 12.9 percentage points, or 27.51 to 62.6 percent of the baseline profitability for the three largest sizes. These results are shown in Table 3-9b.

3.2.2.3 Price Elasticity of Demand

Chrome pigments are intermediate materials used in the manufacture of various end products such as paints, printing inks, and plastics. The extent to which chrome pigments producers can increase prices to recover pollution control costs is primarily determined by the degree that price pass-through is possible in these end markets. End users of chrome pigments would be cushioned from the full impact of the price increase.

For example, paints (accounting for over 60 percent of total chrome pigments consumption) require approximately 0.09 pounds of chrome pigments for each gallon of paint produced. A 15 percent increase in chrome pigments prices would raise the cost of paint by 1.1 cents per gallon. Average unit value data on paint products ranged from five to ten dollars per gallon. Assuming a price of $7.50 per gallon, paint prices would need to increase by 0.15 percent to fully recover the higher cost of chrome pigments. Current demand for paint appears strong enough to

TABLE 3-9a

PROFITABILITY CHANGE

Chemical: Chrome Pigments

Level: BAT/PSES*

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
1,650	10.96%	-6.96%	-17.92% (-163.50%)	10.38%	**	**
4,400	20.89	9.53	-11.36 (-54.38%)	20.59	8.92%	-11.67% (-56.68%)
6,600	27.20	16.00	-11.20 (-41.18%)	25.71	15.92	-9.79 (-38.08%)
19,800	54.41	34.94	-19.47 (-35.78%)	44.38	32.83	-11.55 (-26.03%)

* For this subcategory, BAT and PSES costs are equivalent.

**Negative profitability.

TABLE 3-9b

PROFITABILITY CHANGE

Chemical: Chrome Pigments

Level: BAT/PSES* plus RCRA-ISS

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
1,650	10.96%	-8.83%	-19.79% (-180.57%)	10.38%	**	**
4,400	20.89	8.25	-12.64 (-60.51%)	20.59	7.70%	-12.89% (-62.60%)
6,600	27.20	14.88	-12.32 (-45.29%)	25.71	14.91	-10.80 (-42.01%)
19,800	54.41	33.56	-20.85 (-38.32%)	44.38	32.17	-12.21 (-27.51%)

* For this subcategory, BAT and PSES costs are equivalent.

**Negative profitability.

support this minimal price increase. Since this price increase represents only one cent per gallon, demand for chrome pigments is not likely to be affected significantly. Further, available organic substitutes are four to ten times the cost of chrome pigments. These observations imply relatively inelastic demand.

However, domestic chrome pigment producers must compete with lower-priced imports which will constrain price increases. Further, end users of chrome pigment-containing products may switch to products that do not require the special qualities of chrome pigments. For example, equipment producers may choose to use paint colors (e.g., gray, blue) that do not use chrome pigments in their manufacture. Because of these factors, demand for chrome pigments is assumed moderately elastic. (See Sections 3.1.1, Demand, and 3.1.3, Competition, for a complete analysis.)

3.2.2.4 Capital Analysis

Raising capital to install new pollution control equipment is a potential problem for industries trying to comply with new regulations. In this instance the capital requirements of complying with pollution control regulations will pose a problem. For all model plant sizes the capital costs of PSES/BAT are approximately 32 to 37 percent of the present fixed investment of the plant (see Table 3-10). There are no additional capital requirements to comply with RCRA-ISS requirements because it is assumed that all chrome pigments plants will dispose of their wastes in an off-site landfill.

3.2.2.5 Closure Analysis

Table 3-11 summarizes the price elasticity of demand, price rise, and profitability decline for chrome pigments model plants and compares these to EPA's closure criteria (see methodology description).

The costs of installing and operating BAT/PSES removal level equipment will impose significant impacts on all four model plants, with the

TABLE 3-10

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Chrome Pigments

	Model Plant Production (tons/year)			
Level of Removal	1,650	4,400	6,600	19,800
BAT/PSES*	37.03%	33.35%	32.35%	36.05%
BAT/PSES* plus RCRA-ISS+	37.03	33.35	32.35	36.05

* For this subcategory, BAT and PSES costs are equivalent.

+ It is assumed that all chrome pigment plants will dispose of their wastes in an off-site landfill; therefore, there are no incremental capital costs required for compliance with RCRA-ISS.

TABLE 3-11

IMPACT SUMMARY

Chemical: Chrome Pigments

	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
CLOSURE CRITERIA DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater Than 10 Percent of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PERCENTAGE POINT PROFITABILITY DECLINE (% DECLINE)	CLOSURES
BAT/PSES**	1,650	Medium	14.03%	17.92%* (163.50%)*	May result in any of the size categories
	4,400		8.63	11.67 (56.68)	
	6,600		7.37	9.79 (38.08)	
	19,800		5.54	11.55 (26.03)	
BAT/PSES** plus RCRA-ISS	1,650	Medium	15.36	19.79%* (180.57%)*	May result in any of the size categories
	4,400		9.15	12.89 (62.60)	
	6,600		8.04	10.30 (42.01)	
	19,800		5.97	12.21 (27.51)	

* Based on ROI.

**For this subcategory, BAT and PSES costs are equivalent.

SOURCE: EEA estimates.

impacts being particularly severe for the smallest model plant. The price rise required to recover pollution control costs is much greater than one percent for all models, ranging from 5.5 percent for the largest plant size to 14 percent for the smallest model. Similarly, profitability impacts are large with declines in the ROI ranging from 11 to 19 percentage points. These declines represent 26 to significantly over 100 percent of the baseline profitability. Thus, according to EPA's closure criteria, plant closures are possible for all model plant sizes. While plant closures are possible in all size categories, immediate plant shutdowns are most probable in the smallest size category where the potential decline in profitability is significantly higher and baseline profitability lower than in the other three models. The implications of this model plant closure analysis for actual plants in the industry are discussed in detail in the following section.

The incremental costs of complying with RCRA-ISS requirements are relatively small compared to BAT/PSES removal costs. Therefore, further plant closures are not expected to result from the additional RCRA-ISS costs.

3.2.3 Industry Impacts

In this section the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on chrome pigments manufacturers.

3.2.3.1 Price and Profitability Impacts

The price rise necessary to fully pass through effluent control costs is likely to present a significant problem for chrome pigments producers. In all cases a 5.5 to 14 percent price increase would be necessary. Two factors will constrain a price increase: the potential market shift to organic pigments and competition from imports. While organic pigments are currently much higher in price, some pigment users are now choosing them to avoid the current and anticipated health and regulatory problems associated with many lead-containing chrome pigments. A price increase in chrome pigments will only accelerate this move to organics. Imports also report a significant constraint in price increases. Imports are currently very cost competitive and will become even more so with further domestic price increases. Thus, profit margins and profitability will decline. Given current profitability levels in the industry, the profitability decline is likely to cause hardship. The model plant costs indicate that the smaller plants are operating at close to the break even point, and even a small profitability decline could encourage them to cease operations.

The gradual decline in demand that the industry is experiencing (due, in part, to its problems with OSHA regulation of toxics) would normally lead to plant closures with the least profitable plants closing first. The profitability decline which would result from effluent control regulation will serve to accelerate this rate of closure. The likelihood of plant closure is discussed in more detail in Section 3.2.3.2, Projected Plant Closures.

The incremental price rise and profitability impacts of RCRA-ISS costs are relatively small in comparison to the impacts of effluent control costs. The price of pigments would have to be raised an additional 0.43 to 1.33 percent. Similarly, the incremental decline in profitability (one to two percentage points) would be small relative to the profitability impacts of BAT/PSES costs.

3.2.3.2 Projected Plant Closures

A breakdown of chrome pigments producers according to model plant size is presented in Table 3-12. The five small plants and three medium plants account for approximately one-fourth of subcategory production and employment. The four largest firms dominate industry production and employment (about 76 percent of the total).

The closure projections can be summarized as follows:

TABLE 3-12

CHROME PIGMENTS INDUSTRY CHARACTERIZATION

Model Plant Production (ton/year)	Number of Actual Plants Corresponding To That Model	Estimated Total Production	Estimated Total Employment*
1,650	5	6,000	60
4,400	3	11,000	110
6,600	2	18,000	180
19,800	2	37,500	380
Totals for Subcategory	12	72,500	730

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*Based on 10 employees per thousand pounds of production.

SOURCE: Industry Sources and Technical Contractor Survey

- As mentioned in Section 3.2.3.1, it is unlikely that chrome pigments plants can achieve a full price pass through due to declining demand and import competition. Small plants are currently marginally profitable and any further profitability decline may cause closures. At most, of the two non-exempt small plants, one will close its chrome pigments production line.

- Large plants are more profitable and able to withstand a short-term profitability decline. Full price pass-through is more likely in the long run and given the demand outlook for chrome pigments, these plants will continue to operate at current production levels.

- Medium plants have profitability levels between those of the small and large plants. Of the three medium plants, at most one will close its chrome pigments production line.

These projections are detailed below.

Small Plants

Given the inability of achieving full pass-through of effluent control and RCRA-ISS costs in the short run, the two non-exempt small plants will suffer significant profitability declines (approximately 20 percentage points, representing a 181 percent profitability decrease, with combined effluent and RCRA-ISS costs). Cost and price data and industry sources indicate that the chrome pigments manufacturers corresponding to this model size are currently only marginally profitable. Therefore, the potential decline in profitability resulting from producers' inability to fully pass through pollution control costs may result in plant or production line closures. Another significant factor for these small manufacturers is the potential difficulty in securing the capital necessary for investment in pollution control equipment, representing 37 percent of fixed investment in place. Three of the five producers in this size category are small privately-owned companies rather than parts of large chemical conglomerates and, therefore, may have more difficulty in accessing capital markets.

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However, it is unlikely that both of the non-exempt small plants will close their chrome pigment production lines. Since one plant is involved solely in chrome oxide green production, it will not be affected by OSHA's further limitations on worker exposure to lead and will not face the high costs of compliance with these regulations. Further, demand for chrome oxide green is much stronger than for the other chrome pigments and sustained demand strength will probably allow this small producer to pass-through part of the control costs to customers. Therefore, it is less likely to close its chrome pigments product line than other small chrome pigments plants which must comply with both OSHA and EPA regulations.

In the case of the most heavily affected plant, it is likely to shutdown its chrome pigments operations. However, this plant is unlikely to close in its entirety, as chrome pigments represents only 10 percent of the plant's annual production.

Large Plants

Larger plants in the industry may be willing to experience the short-run profitability declines and attempt to recover the pollution control costs over several years through periodic price increases. Although the model plant analysis indicates large declines in profitability for these producers, the profitability levels after control are still sufficient to justify continued operation, at least in the short run. Thus pollution control costs are not likely to result in immediate plant closures for larger producers. However, larger manufacturers' actions will be determined by the long-run demand outlook for chrome pigments. If future demand appears insufficient to justify sizeable capital investment and temporary profitability declines, further plant closures can be expected in the larger size categories.

In order to evaluate the future U.S. market for chrome pigments, 1985 demand is projected based on the following assumptions:

- Current industry projections for chrome pigments demand growth are accurate. The most pessimistic projections are that demand will decline from 1979 levels for lead-containing pigments (chrome yellow and orange, molybdate chrome orange, and chrome green) because of more stringent OSHA standards and increasing consumer concern over adverse health effects of lead exposure. Demand for other chrome pigments (zinc yellow and chrome oxide green) will continue to grow with GNP since they will not face the serious lead pollution problems experienced by other chrome pigments.

- Because foreign producers' response to future U.S. demand cannot be predicted with certainty, import projections are based on import level performance in recent years. In the projected demand scenario, imports are assumed to achieve the maximum penetration levels observed during the years 1972-1979.

Table 3-13 presents the estimated demand, potential import penetration and market for domestic producers in 1985 based on the above assumptions. The projected market for domestic producers in 1985 is approximately 57,000 tons.* This market is sufficient to justify the continued operation of the four largest domestic producers (corresponding to the two largest model sizes) whose combined estimated production is currently 55,500 tons per year (see Table 3-12).

The projection of 57,000 tons may underestimate the 1985 domestic market since import penetration is unlikely to reach the 21 percent level assumed in this analysis. One International Trade Commission expert** estimates that a 10 percent increase in domestic chrome pigment prices would result in imports' market share increasing only a few percentage

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* This projection is based on a "worst case" demand growth assumption for lead-containing chrome pigments, i.e., that demand will actually fall from 1979 levels. Since some decline in demand is already reflected by the 1979 production levels, it is also possible that demand for lead-containing chrome pigments will stabilize at 1979 levels. In this case, the projected domestic market in 1985 is 68,000 tons, clearly sufficient to justify the continued operation of the four largest plants in the subcategory.

** Mr. Larry Johnson, telephone conversation, January 18, 1980.

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TABLE 3-13

PROJECTED CHROME PIGMENTS DEMAND - 1985

Chrome Pigment	1979 Demand 1/ (tons)	Estimated Annual Growth 2/	1985 Demand (tons)	Maximum Potential Import Penetration 3/ (tons)	Market for Domestic Producers - 1985 (tons)
Chrome Oxide Green	14,327	2.5%	16,615	2,913	13,702
Zinc Yellow	5,783	2.5	6,707	2,146	4,561
Chrome Yellow & Orange	35,841	-1.95	31,847	5,746	26,101
Molybdate Chrome Orange	15,230	-1.50	13,910	3,621	10,289
Chrome Green	3,355	-1.95	2,981	418	2,563
TOTALS	74,536		72,060	14,844	57,216

1/ Estimates of U.S. 1979 annual production and 1979 imports reported by Bureau of the Census. (Inventories assumed unchanged.)

2/ Based on historical trends and industry sources (1974-1979).

3/ Assuming maximum import penetration levels (as percent of total demand) 1972-1979 are reached for each pigment.

SOURCES: Bureau of the Census, Technical Contractor Survey, EEA Estimates points above their current level of eight percent and suggests that 11 or 12 percent represents a reasonable import penetration figure. Therefore, the actual domestic market is more likely to be approximately 63,500 tons in 1985 (under the negative demand growth assumptions used above).

An examination of the large chrome pigments plants reveals other significant factors that will encourage them to remain in operation. One large producer is currently meeting BAT limitations and will therefore not incur new effluent control costs. Another large producer is one of two present manufacturers of zinc yellow (the other is a small plant identified as a probable closure candidate) and is not as likely to cease production given the relatively optimistic outlook for continued demand growth for this pigment. Based on projected industry demand and examination of the actual producers, no plant closures are forecast for the four producers corresponding to the two largest model plants.

Medium Plants

The profitability decline and required price rise for the medium-sized producers will fall between those for the small and the larger plants. Of the three medium-sized producers in the chrome pigments industry, two plants are likely to maintain chrome pigments production. One plant produces only chrome oxide green and is therefore expected to continue operating since chrome oxide green will not face increased worker safety costs and is expected to experience continued demand growth. A second plant is already in compliance with the regulations. The third medium-sized producer manufactures chrome yellow and molybdate chrome orange. Effluent control and OSHA costs, along with declining demand for these pigments, may encourage this producer to close its chrome pigments production line over the next five years. As in the case of the small-size closure candidate, chrome pigments sales are estimated to account for less than ten percent of the plant's revenues. The plant is therefore likely to continue operations independent of the viability of its chrome pigments line.

3.2.3.3 Other Impacts and Conclusion

At most, one immediate production line closure is predicted for small chrome pigments producers with one additional line closure possible for medium-sized producers within the next five years. If both of these producers were to discontinue chrome pigments production, unemployment could result for approximately 60 persons, or 8 percent of subcategory employment (see Table 3-12). Reabsorbing these unemployed workers into the local labor force could be difficult; both producers are located in metropolitan areas with current unemployment rates (as of April 1981) above the national average. However, both plants are operated by large manufacturing companies and intra-company transfers could mitigate job displacement resulting from plant closures.

If the production line clsoures discussed above occur no permanent supply disruption is predicted. The two closure candidates account for approximately 8 percent of estimated subcategory production. With the industry currently operating at approximately 75 percent capacity, larger producers will be able to expand production sufficiently to meet demand for chrome pigments. In addition, imports are available for all types of chrome pigments and could alleviate any temporary bottlenecks in domestic supply. Industry concentration will not be significantly affected by the plant closures and no single producer is expected to gain significant market power that might allow monopoly pricing.

Currently imported chrome pigments account for only 8 percent of U.S. consumption. However imports are expected to become a more significant factor in the domestic market for two reasons:

- The availability of imported pigments will act as a constraint on the price increases achievable by domestic producers attempting to pass through pollution control costs.
- As worker safety and pollution control costs increase the price differential between domestic and imported chrome pigments, imports can be expected to capture a larger share of the market. However, import penetration is not expected to increase beyond 12 percent.*

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* Mr. Larry Johnson, International Trade Commission, telephone communication, January 18, 1980.

4. COPPER SULFATE

4.1 CHARACTERIZATION

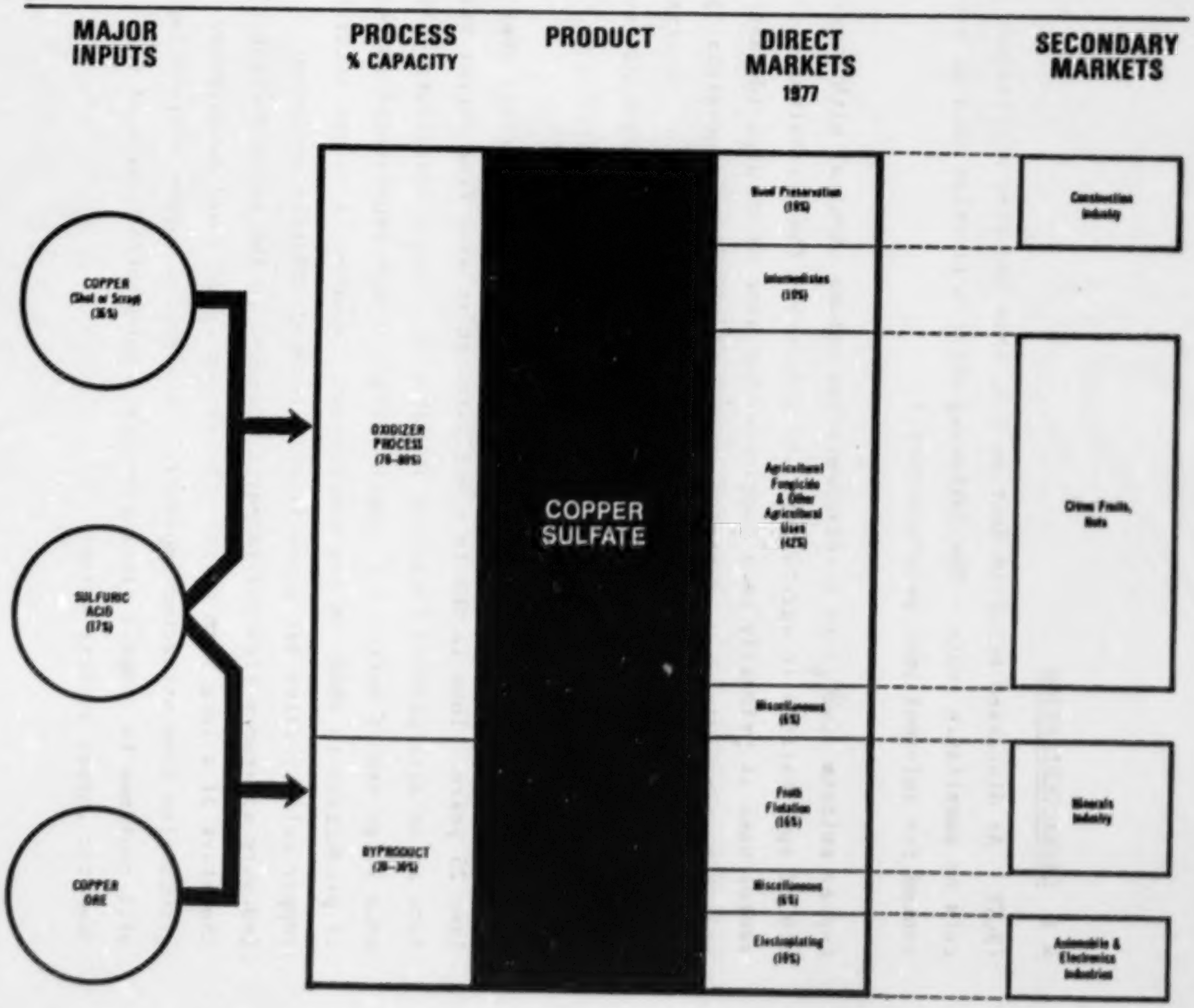
(NOTE: As discussed below in Section 4.2, this industry subcategory incurs no compliance costs. The following characterization data is presented for informational purposes only.)

Copper sulfate ($CuSO_4$) is a relatively low volume chemical with a variety of applications in agriculture and industry. The agricultural sector uses it primarily as a fungicide, but also as an algicide and a micronutrient additive in fertilizers and animal feeds. Industrially, copper sulfate is used in froth flotation, wood preservation, electroplating, leather tanning, dye manufacture, and petroleum refining (see Figure 4-1 for sources and uses of copper sulfate).

Domestic production of copper sulfate has declined dramatically over the last 25 years. This is due to a worldwide shift away from copper sulfate as an agricultural fungicide in favor of organic fungicides. The once large export market for copper sulfate (which represented 24 percent of production in 1960) is now nonexistent. However, a recent upturn in copper sulfate sales has given rise to renewed industry optimism. Industry spokesmen view the recent turnaround in the sales decline as the start of a long term trend. The strong markets and anticipated growth also have attracted importers. Low priced copper sulfate imports will continue to compete vigorously for a substantial share of the domestic copper sulfate market.

FIGURE 4-1

COPPER SULFATE:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
COPPER (Shot or Scrap) (35%)
SULFURIC ACID (17%)
COPPER ORE
OXIDIZER PROCESS (70-80%)
BYPRODUCT (20-30%)
COPPER SULFATE
Wood Preservation (10%)
Intermediates (10%)
Agricultural Fungicide & Other Agricultural Uses (42%)
Miscellaneous (6%)
Froth Flotation (16%)
Miscellaneous (6%)
Electroplating (10%)
Construction Industry
Citrus Fruits, Nuts
Minerals Industry
Automobile & Electronics Industries

4.1.1 Demand

4.1.1.1. Agricultural Fungicides and Other Agricultural Uses

The agricultural sector accounted for 42 percent of copper sulfate consumption in 1977. Most of this was used as a fungicide in the form of the "Bordeaux mixture," a simple mixture of hydrated lime and copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$).

Fungicides are essential to the agricultural industry. The investment return is about two to four dollars in crops for every dollar of fungicide applied. Their effectiveness has yielded a strong and steadily growing demand for agricultural fungicides: total sales were 112 million dollars in 1975; growth in demand will be about seven percent annually through 1985. (Chemical and Engineering News, September 5, 1977).

Copper sulfate, once one of the two most widely used fungicides, now holds less than 15 percent of the agricultural fungicide market. In either the Bordeaux mixture or unmixed (basic) form, copper sulfate acts to inhibit the inception of fungus growth. It is used on citrus fruits, deciduous fruits, and nuts. Together with sulfur compounds, copper sulfate fungicides control about one-third of the fruit and nut market. (Chemical Purchasing, February 1978).

In addition to its use as a fungicide, copper sulfate is used as an algicide, in seed treatment, and as an additive in feeds and fertilizers to correct for copper deficiencies in poultry and plants.

Demand for copper sulfate in its agricultural end uses fluctuates with agricultural demand, which is highly variable. Demand for fungicides is also affected by rainfall (fungus growth is encouraged by damp conditions) causing fungicide sales to be robust during rainy periods and slack during dry spells. Demand varies regionally for the same reason.

4.1.1.2 Industrial Uses

Copper sulfate is used in a variety of industrial applications. Each of these markets will be discussed separately.

Froth Flotation

Copper sulfate is one of the most widely used froth flotation agents. This market accounted for approximately 16 percent of copper sulfate demand in 1977. Froth flotation is a refining process used in separating metals (primarily zinc) from their ores. Because the use of froth flotation agents is application specific, copper sulfate's froth flotation end use market is secure. Moderate demand growth (three to five percent annually) is expected in this market.

Wood Preservation

Approximately 10 percent of copper sulfate production is used in the manufacture of the wood preservative chromated copper arsenate (CCA). This substance binds chemically to wood, rendering it impervious to fungus. Large quantities of wood preservatives are used by the construction industry to protect wood exposed to damp conditions. (Chemical Purchasing, February 1978).

Electroplating

The electroplating industry accounts for about 10 percent of copper sulfate consumption. Electroplating is a process whereby objects are coated with a thin layer of one or more metals in order to improve the appearance, durability, or electrical properties of the surface. The process involves placing the object in a bath containing a metal salt. An electric current is passed through the solution and the object such that the metal from the salt (copper in the copper sulfate solution) attaches itself to the surface of the object.

Copper plating is used to improve heat conductivity (as in cookware), to improve electrical conductivity in electrical equipment, and as a first coat before nickel and chromium on automobile parts.

There is some concern that demand for copper sulfate from the electroplating industry may fall off during the early 1980's as the industry begins to recycle the spent copper sulfate solution in order to reduce flow. However, only a small portion of the industry has begun to recycle because recycling systems are expensive and involve separation of wastewater.

The number of manufacturers recycling copper sulfate solution may increase with rising copper prices and stringent discharge requirements. This may reduce demand for copper sulfate from the electroplating industry. Nevertheless, one major copper sulfate producer currently is experiencing rising demand for the chemical from metal platers, and expects the trend to continue.

Other Industrial Uses

Copper sulfate is used in dye manufacture, leather tanning and hide preservation, as a "sweetener" for sulfur removal in petroleum refining, and as a starting material for other copper salts. Copper sulfate also is used as an algicide in municipal water treatment and reservoirs. (Chemical Purchasing, February 1978).

4.1.1.3 Demand Summary

Copper sulfate has a number of end uses in both agricultural and industrial markets:

- Agricultural fungicides and other agricultural uses (42 percent of copper sulfate demand in 1977)
- Froth flotation (16 percent)
- Wood preservation (10 percent)

- Electroplating (10 percent)
- Intermediates (10 percent)
- Miscellaneous (12 percent)

Demand for copper sulfate declined at a rate of 3.3 percent per year between 1968 and 1977 (see Table 4-1). While market demand for some end uses (particularly froth flotation and wood preservation) will experience moderate growth in the early and mid-1980's, these growing markets are too small to have a great impact on overall demand. Whether this decline will continue at the same rate or turn around (as some producers have predicted) is not clear.

4.1.2 Supply

4.1.2.1 Production

Production of copper sulfate has suffered a rather precipitous decline since World War II, when large quantities were produced for export as an agricultural fungicide. This foreign demand disappeared with the introduction of organic fungicides in the 1940's, and production has fallen from over 80 thousand short tons in 1955 to a low of 30.1 thousand tons in 1977. Production rose by 17 percent in 1978 to 35.1 thousand tons leading industry spokesmen optimistically to forecast a period of renewed interest in copper sulfate. (Chemical Marketing Reporter, September 11, 1978). This forecast may be premature, especially in light of the chemical's recent production history. (See Table 4-1 and Graph 4-1.)

4.1.2.2 Producers

There are eleven firms that manufacture copper sulfate (see Table 4-2). Individual plant production capacities are unavailable.

TABLE 4-1

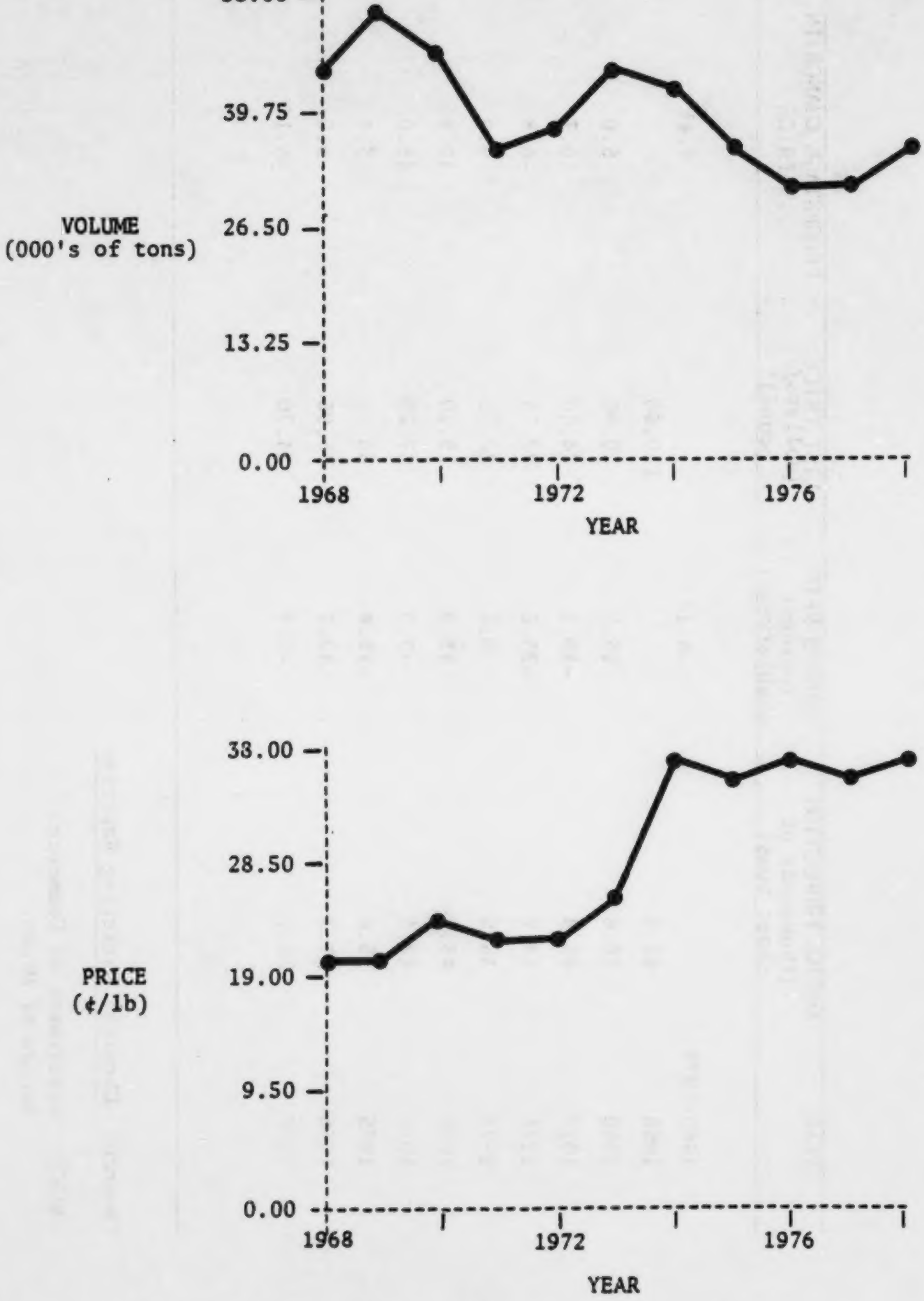
PRODUCTION OF COPPER SULFATE

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change/year)	LIST PRICE (dollars/ pound)*	PERCENTAGE CHANGE IN PRICE
1968-1978		-4.1%		6.4%
1968	43.8		$19.90	
1969	50.6	15.5	20.90	5.0
1970	45.4	-10.3	24.40	16.7
1971	34.7	-23.6	22.75	-6.8
1972	38.0	9.5	22.75	0.0
1973	43.1	13.9	25.20	10.8
1974	42.1	-3.0	37.20	48.0
1975	35.6	-15.4	35.20	5.4
1976	31.3	-12.1	36.95	5.0
1977	30.1	-3.8	34.70	-6.1

*Source: Chemical Marketing Reporter

SOURCE: Department of Commerce.
Bureau of Mines.

GRAPH 4-1
COPPER SULFATE PRODUCTION AND PRICE



SOURCE: Department of Comm[illegible]

TABLE 4-2

PRODUCERS OF COPPER SULFATE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
Cities Service Co., Inc. North American Chemical and Industrial Chemical Division	Copperhill, TN	N/A	*	Copper Sulfuric Acid	
CP Chemicals, Inc.	Sewaren, NJ Powder Springs, GA	N/A	*		
Phelps Dodge Corp. Phelps Dodge Refining Corp. Subsidiary	El Paso, TX Maspeth, NY	N/A	*	Copper Sulfuric Acid	
Chevon Chemical Co.	Richmond, CA				
Imperial West Chemical Co.		N/A			
Kocide Chemicals Co.	Houston, TX	N/A			
Liquid Chemical Corp.	Hanford, CA	N/A			
Mallinckrodt Chemical	St. Louis, MO	N/A			
Southern California Chemical Co.	Bayonne, NJ	N/A			
	Sunte Fe Springs, CA				
	Union, IL	N/A			
Univar Corp.	Metaline Falls, WA Midvale, Utah Pinehurst, ID	N/A			
Van Waters & Rogers	Wallace, ID	N/A			

N/A = Not Available.

* These three producers together account for more than 90 percent of industry production (Department of Commerce).

Phelps Dodge and Cities Service, the two largest producers, account for 80 percent of domestic copper sulfate manufacture, according to one industry source. CP Chemicals is the third major producer with approximately 10 to 15 percent of industry production. The remaining eight producers market only small quantities of copper sulfate.

Due to the nature of the industry and the copper sulfate market, the list of firms claiming copper sulfate production changes often. The production process is relatively simple and capital equipment requirements are low compared to those of an ore refining operation. Therefore, firms find it feasible to enter the market in periods of increased demand and withdraw when demand declines. For example, Anaconda Company produces copper sulfate as a by-product in their copper refining process. However, they serve only available local markets and have not marketed any copper sulfate for some time. They have stated that they intend to re-enter the copper sulfate market in the future.

Two of the three largest producers, Phelps Dodge and Cities Service, are copper refiners. They are, therefore, integrated backward to copper sulfate's main constituent.

4.1.2.3 Process

The principal inputs for the production of copper sulfate are copper, sulfuric acid, and oxygen. Approximately 20-30 percent of the total volume of copper sulfate production is a by-product of copper refining. During refining, copper is leached from its ores with sulfuric acid. Most of the resulting copper sulfate solution is treated to remove pure copper, but some of the solution is removed to eliminate impurities. Commercial-grade copper sulfate can be recovered from this by-product.

Copper sulfate also is produced by action of sulfuric acid on scrap or copper shot. The resulting copper sulfate solution is allowed to settle and evaporate to form crystalline cupric sulfate. The reaction in this process is:

$$2Cu + 2H_2SO_4 + O_2 \rightarrow 2CuSO_4 + 2H_2O$$

There are no significant co-products or by-products of the process. Most production wastes are recycled to recover copper.

Estimated manufacturing costs and capital costs for copper sulfate production are presented in Table 4-3. Raw material copper costs account for 35 to 42 percent of total manufacturing costs. Capital investment is approximately $770 per ton of capacity which is moderately high. (Capital costs in inorganic chemicals manufacture range from 300 dollars per ton to 1500 dollars per ton, depending on the chemical produced and the process used.) However, total capital investment is small compared to copper refinery equipment, according to industry sources.

4.1.3 Competition

There are three sources of competition facing a copper sulfate producer:

- Competition from other producers of copper sulfate;
- Import competition;
- Competition from products which may serve as substitutes for copper sulfate in each of its end uses.

Each of these will be discussed separately.

4.1.3.1 Intra-industry Competition

One way in which a producer of a fairly homogeneous product, such as chemicals, will compete is by differentiating the product slightly. In the chemical industry, this often takes the form of performing additional finishing steps to improve the chemical's properties according to the requirements of a specialized market. Copper sulfate is manufac-

TABLE 4-3

ESTIMATED COST OF MANUFACTURING COPPER SULFATE*
(mid-1978 dollars)

Plant Capacity	2,850 tons/year
Annual Production	2,250 tons/year (79% capacity utilization)
Fixed Investment	$2.2 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Copper Shot (scrap)	480.71 lb	.55	264.40
- Sulfuric Acid (66 Be´)	801.79 lb	.016	12.80
• Utilities			
- Power	90.70 kWh	.03	2.70
- Steam	9.07 klb	3.25	29.50
- Cooling Water	5.44 kgal	.10	.50
- Process Water	3.27 kgal	.75	2.50
Total Variable Costs			$312.40
SEMI-VARIABLE COSTS			
• Labor			141.00
• Maintenance			34.50
Total Semi-Variable Costs			$175.50
FIXED COSTS			
• Plant Overhead			35.30
• Depreciation			86.10
• Taxes & Insurance			12.90
Total Fixed Costs			$134.30
TOTAL COST OF MANUFACTURE			$622.20

SOURCE: Contractor and EEA estimates

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*See Appendix C

tured in a number of forms (grades) in an attempt to appeal to specialized markets.

Pentahydrate is sold in technical, United States Pharmaceutical (U.S.P.) and chemically pure (CP) grades. The technical grade is used in Bordeaux mixture, metal plating, water treatment, wood preservation, and algicides. Chemically pure copper sulfate has specialized applications. The purification procedure is expensive and is reflected in CP's higher price, almost twice that of the technical grade. At least one company (Mallinkrodt) manufactures only chemically pure copper sulfate. (Chemical Purchasing, February 1978).

Basic copper sulfate (also known as Tri-Basic, the registered trademark of Cities Service's basic product) is used as a fungicide on citrus fruits. Both pentahydrate and basic are sold in four pound and 100 pound bags.

4.1.3.2 Import Competition

Imports of copper sulfate (primarily from Spain) have risen during the last three years from 460 short tons in 1975 to 2,700 in 1977, a six-fold increase. Imports captured nearly 10 percent of the market in 1977. Import prices are about 20 percent lower than domestic prices. This has forced domestic producers to sell copper sulfate at less than published list prices in order to remain competitive. U.S. producers have claimed that imported copper sulfate is highly impure, overly acidic, and generally inferior to the domestic chemical. There also have been murmurings of possible dumping (sale of imports at below cost, which is a violation of trade regulations) but no suits have been filed.

All of these charges have been refuted by the leading importer of copper sulfate, Calabrian International Corporation. A spokesman for Calabrian claims that importers of copper sulfate are, in fact, at a disadvantage.

Copper sulfate used as algicides must be registered with EPA, and registration is sometimes difficult. This has resulted in domestic producers reducing prices only in markets where there is import competition, and selling at list price where there is no import competition. Imports will remain a significant competitive force in the domestic copper sulfate market (Chemical Marketing Reporter, September 11, 1978).

4.1.3.3 Substitute Competition

Copper sulfate's major market, agricultural fungicides, has declined with the introduction of new and more effective products. The organic fungicides usurped many of copper sulfate's markets because they are as good a fungal deterrent and have the added advantage of being able to arrest fungal infection after it has started. While unit costs of the organics are higher, labor and application costs are lower. The dithiocarbonate group of organic fungicide almost eliminated the use of copper sulfate on bananas by 1960. (Chemical Purchasing, February 1978).

Copper sulfate's share of the agricultural fungicide market has dropped to 10 to 25 percent. Recently, however, there has been a renewed interest in copper sulfate fungicides due to a suspicion that the organics may be carcinogens. Whether this will boost sales of copper sulfate in the fungicide market is uncertain.

Copper sulfate is an ingredient in chromated copper arsenate (CCA), a wood preservative. As such, it competes with two other wood preservatives: pentachorophenal (PCP) and creosote. PCP may lose some of its market to CCA because it is under investigation for possible toxic effects. PCP use has been limited by the State of Michigan, where it is suspected of having caused the illness and death of dairy herds. (Chemical Purchasing, March 1978).

Overall, demand for copper sulfate seems to be dependent on price; buyers will switch to substitutes as the relative price of copper sulfate rises. It is possible that the suspected health hazard posed by some of copper sulfate's major end use substitutes may result in increased copper sulfate demand.

4.1.4 Economic Outlook

4.1.4.1 Revenue

Total revenue is the product of quantity sold and average unit price. Although these two variables are discussed separately, they are interrelated.

4.1.4.1.1 Quantity

Both domestic copper sulfate production and import volumes are rising. Considering the chemical's recent history of short term surges and declines in production, it is too early to tell if the current production increase is a long term trend or merely another fluctuation. Producers of copper sulfate view the production gains of the last year as the beginning of a five year increase in demand for copper sulfate, although they seem uncertain about the source of the demand. Nevertheless, their enthusiasm attracted one new manufacturer, brought on stream in late 1978. (Chemical Marketing Reporter, September 11, 1978).

Copper sulfate is in the latter (mature) stage of its product life cycle, and its use has been declining. The only end uses that seem to have growth potential are wood preservation and froth flotation. Copper sulfate's use as an agricultural fungicide probably will continue to decline, although it will retain its share in some applications. Growth in other end uses will parallel that of the Gross National Product. Recent producer optimism may be due to short term factors affecting demand, such as low prices and the questions being raised by health officials about products which compete with copper sulfate.

4.1.4.1.2 Price

The single most important factor in the price of copper sulfate pentahydrate is the price of copper.

Price is also influenced by market factors. Low priced imports will continue to force domestic producers to sell below list prices in those end markets where imports are a threat.

4.1.4.2 Manufacturing Costs

Copper is the primary raw material in the manufacture of copper sulfate. The domestic copper industry currently is depressed due to:

- Overcapacity
- Federal air pollution regulations which required heavy investments in pollution abatement equipment
- Low world copper prices resulting from high production by Third World copper mines

Producer prices for refined copper were 63 cents per pound at the beginning of 1978, 72 cents in late October, and 69 cents by mid-November. The average price was 66 cents, compared with 67 cents in 1977. (Bureau of Mines, January 1979) Continuing reduction in previously large inventories has caused copper prices to rise, however, and the New York Commodity Exchange price of copper rose to $1.00 per pound in March of 1979 (Chemical Marketing Reporter, March 5, 1978).

Production costs for refined copper will continue to rise with the price of energy, as the refinery process is energy intensive. Further cost increases due to pollution control and other government regulations are expected. However, a recently developed refinery process may reduce operating costs by half. Capital costs are approximately one-third those of a conventional process plant, according to the developers of the new technology. (Chemical and Engineering News, March 13, 1978).

4.1.4.3 Profit Margins

The competitive nature of the copper sulfate industry and rising copper prices will combine to keep profit margins narrow during the next few years. Pricing will remain competitive for the following reasons:

- There are a number of manufacturers capable of entering and leaving the copper sulfate market according to prevailing demand conditions.
- Copper sulfate importers vie for market share by pricing below domestic list prices.
- Domestic manufacturers must price low to meet import prices.

The same competitive factors which keep prices low will similarly influence capacity utilization. Waning demand and competition from imports could cause capacity utilization to decline. This will result in higher costs and lower profit margins.

Profit margins will be squeezed further by rising copper prices. According to a study by Chase Econometrics, a worldwide shortage of copper users will push U.S. copper prices to over two dollars per pound by 1985 (Chemical Week, February 21, 1979). The 1980 annual average price for copper was $1.02 per pound (Survey of Current Business, August 1981).

4.1.5 Characterization Summary

Copper sulfate is used primarily as an agricultural fungicide, froth flotation agent, and wood preservative. Other uses include electroplating, tanning, dye manufacture, and petroleum refining. Copper sulfate production has declined during the last ten years due to a worldwide shift to organic fungicides.

Increased copper prices in the mid-1980's will cause copper sulfate's price to increase. Users of copper sulfate will be induced to switch to substitutes. Copper sulfate sales volume will decline due to high price and generally declining end use markets. Further, the higher copper price will encourage more intensive copper recovery efforts, reducing the supply of by-product copper sulfate.

Factors causing production to decline may be mitigated by growth in some end markets if organic substitutes for copper sulfate fungicide are regulated because they are carcinogenic. But even if this happens, other fungicides may be developed to take their place. Overall, the copper sulfate market probably will not grow faster than the GNP, and may continue to decline.

4.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the copper sulfate subcategory to comply with BAT and PSES effluent control standards. EPA has determined that no plants in this subcategory will incur compliance costs under this rulemaking:

- All 15 direct dischargers already have BPT in place, and BAT has been set equal to BPT for this subcategory.
- Pretreatment standards for indirect dischargers were promulgated previously. The current rulemaking revises the limitations to equal BAT, but does not change the technology basis or the compliance costs. Therefore, while the one indirect discharger in the industry may not have treatment in place, the compliance costs it will have to incur are attributable to an earlier PSES rulemaking (40 CFR 415.374). There are no additional compliance costs associated with the current regulation.

Accordingly, these regulations will have no economic impact on the subcategory.

4.2.1 Pollution Control Technology and Costs

As noted above, no plants will incur compliance costs under this rulemaking. The following detail on control technology and costs is presented for informational purposes only.

Capital and operating costs were developed by the technical contractor for pollution control technologies designed to meet BPT levels of waste removal. BPT removal is equivalent to pretreatment. Pollutants from copper sulfate manufacture include copper, zinc, nickel, and arsenic. The wastewater is treated in a batch process to achieve BPT/PSES:

- After reaching a holding tank, caustic soda is added to the effluent to precipitate metals.
- Overflow from the settling tank is filtered.
- Solids are landfilled.

Pollution control cost estimates were developed for one model plant, with an annual production rate of 2,300 tons. Table 4-4 summarizes pollution control costs for the model plant.

TABLE 4-4: POLLUTION CONTROL COSTS

Chemical: Copper Sulfate

Model Plant Production (tons/year)	BPT/PSES		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
2,300	$128,249	$30,622	For this subcategory, BAT is the same as BPT. There are no incremental costs over BPT for compliance with BAT regulations.	

Source: Technical Contractor

5. HYDROGEN CYANIDE

5.1 CHARACTERIZATION

Hydrogen cyanide (HCN) is a highly toxic chemical used as an intermediate in the production of plastics, herbicides, and fibers (see Figure 5-1). The hydrogen cyanide industry is characterized by a high degree of captive use: of the 198,000 short tons produced in 1977, industry sources estimate that more than 90 percent was used by the manufacturer in the production of "downstream" chemicals. These chemicals are:

- Methyl methacrylate (60 percent of HCN use in 1977) used to make plastics such as Rohm and Haas' PLEXIGLAS® and DuPont's LUCITE®
- Cyanuric chloride (16 percent) used in manufacture of triazene herbicides, a high growth product
- Chelating agents (12 percent) used in metal cleaners, soaps, and industrial water treatment
- Sodium cyanide (9 percent) used in metal treatment and plastic manufacture
- Synthetic methionine and other uses (3 percent)

This breakdown excludes HCN's captive use in the manufacture of adiponitrile, an organic intermediate in nylon 6/6 production. Hydrogen cyanide produced for this purpose is not separated or purified and is, therefore, not included in Bureau of Commerce production statistics. Because HCN used in the production of adiponitrile is not considered a separate product and will be regulated as part of the production process of adiponotrile, it will not be considered here.

The high degree of captive use implies that producers of HCN are guided by the costs and profitability of the downstream chemicals. The costs of reducing effluents from HCN manufacture will be perceived as increased costs in the production of MMA, cyanuric chloride, etc. Thus, the markets and financial conditions for these end-use products give the best indication of the state of the HCN manufacturing industry.

5.1.1 Demand

The demand for HCN is a function of the demand and demand growth of its end markets. To facilitate an understanding of the demand side of the industry each of the end markets for HCN will be discussed separately.

5.1.1.1 End Markets

Methyl Methacrylate (MMA) -- MMA is polymerized to yield a durable acrylic plastic which is used in a number of ways:

- Cast sheet (40 percent) used in glazing applications, outdoor signs, and fluorescent lighting diffusers
- Surface coatings (25 percent)
- Molding and extrusion powders (15 percent) used in automotive headlight lenses
- Oil additives (5 percent)
- Miscellaneous and exports (15 percent)

Approximately 70 percent of the MMA produced is used captively in acrylic production. In 1977, approximately 745,000,000 pounds of MMA were produced (see Table 5-1), using 124,000 tons of HCN. HCN production is closely tied to MMA demand, as indicated by the similarities in the production figures for each. Both HCN and MMA production dropped sharply in 1977 reflecting the slump in MMA's major markets (the automotive and construction industries).

Because MMA's end markets are in major sectors of the economy, demand growth projections usually are based on Gross National Product (GNP)

FIGURE 5-1

HYDROGEN CYANIDE:

INPUTS AND END MARKETS

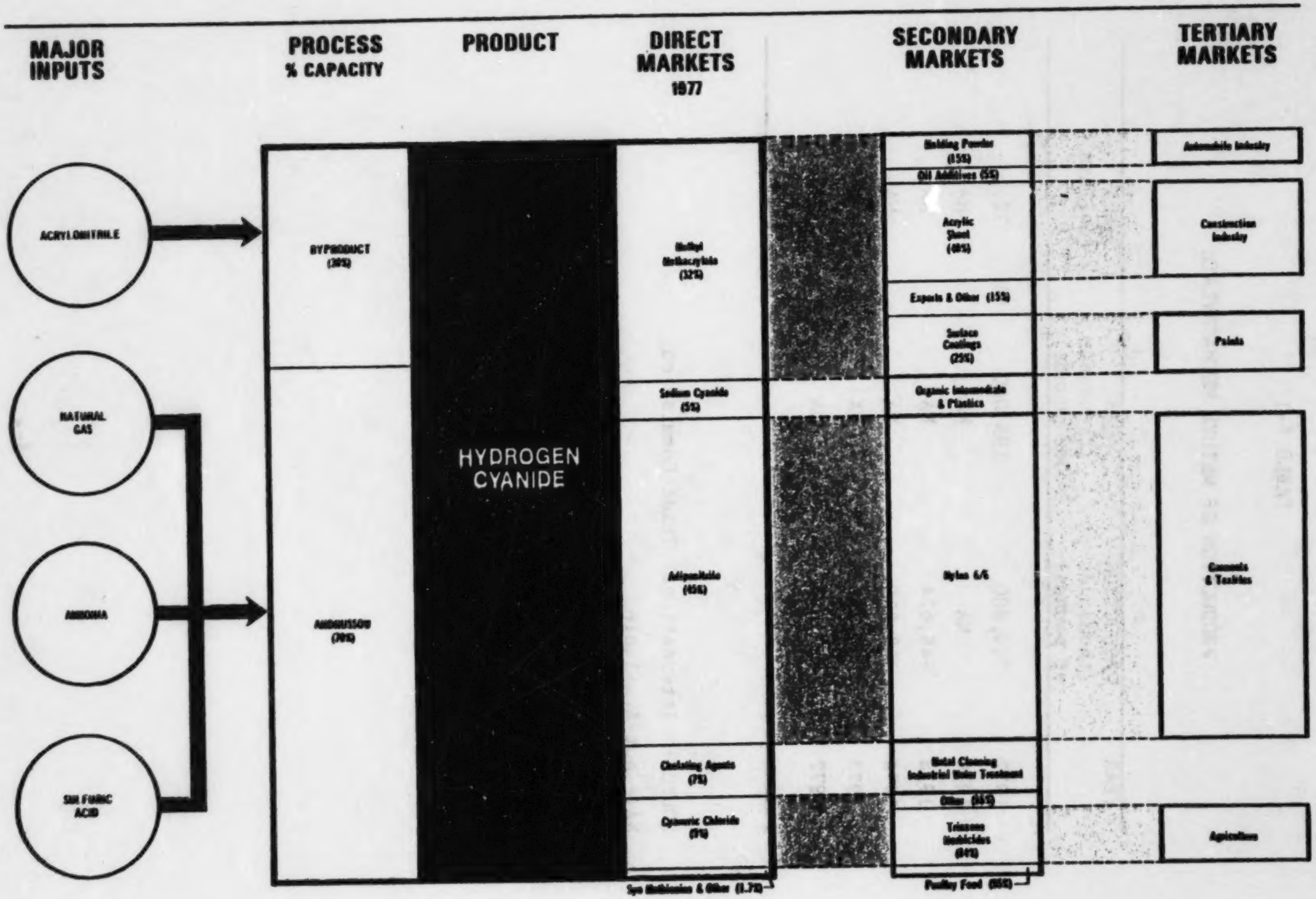

MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
TERTIARY MARKETS
ACRYLONITRILE
NATURAL GAS
AMMONIA
SULFURIC ACID
BYPRODUCT (30%)
ANDRUSSOW (70%)
HYDROGEN CYANIDE
Methyl Methacrylate (32%)
Sodium Cyanide (5%)
Adiponitrile (45%)
Chelating Agents (7%)
Cyanuric Chloride (9%)
Syn Methionine & Other (1.7%)
Molding Powder (15%)
Oil Additives (5%)
Acrylic Sheet (40%)
Exports & Other (15%)
Surface Coatings (25%)
Organic Intermediate & Plastics
Nylon 6/6
Metal Cleaning Industrial Water Treatment
Other (16%)
Triazine Herbicides (84%)
Poultry Feed (85%)
Automobile Industry
Construction Industry
Paints
Garments & Textiles
Agriculture

TABLE 5-1

PRODUCTION OF METHYL METHACRYLATE

YEAR	PRODUCTION (thousands of pounds)	SALES (thousands of pounds)	SALES (dollars)
1977	744,900	195,000	72.1
1976	NA	NA	NA
1975	545,624	NA	NA
1974	718,810	NA	NA
1973	706,295	NA	NA
1972	598,992	NA	NA

SOURCE: International Trade Commission.

NA = Not Available

growth projections. Of the three MMA producers (see Table 5-2), two are forecasting growth at a rate just ahead of GNP growth, while the third foresees growth concurrent with GNP growth -- about three percent per year. Other observers have predicted growth as high as seven percent per year (Chemical Engineering, July 3, 1978). This is a marked reduction from the 15 percent annual growth experienced in the 1960's when MMA first was penetrating its major markets.

While the demand outlook for MMA is reasonably strong, HCN demand probably will not keep pace. A new MMA manufacturing process has been developed which uses no HCN. Conversions to this new process are expected to take place in the early to mid-1980's.

In the conventional ("acetone cyanohydrin") process, acetone and hydrogen cyanide are reacted to form acetone cyanohydrin, which is then reacted with sulfuric acid to form methacrylamide sulfate. This product is then reacted with methanol to yield MMA.

The new technology ("C_4-oxidation") starts with a four carbon molecule (isobutylene or tert-butyl alcohol). The alcohol is oxidized to methacrolein and this is esterified to MMA.

One manufacturer has stated that any new grassroots MMA plant would have to employ the new technology, although older, depreciated, conventional technology plants still could compete (Chemical Engineering, July 3, 1978). Capital costs for a new 300 million lb/year plant are estimated at $113 million; a conventional plant, at $96 million. However, assuming integration back to feedstock tert-butyl alcohol, MMA produced by the new process could be sold for 20 percent less than conventionally produced MMA. (Chemical and Engineering News, July 26, 1976). Plans for adopting this new technology are being made by MMA producers. (See Section 5.1.4.1 for a discussion of the full implications of the new technology.)

Cyanuric Chloride -- Cyanuric chloride is used primarily in the production of triazene herbicides. Worldwide herbicide production uses 84 percent of all cyanuric chloride produced.

Two to three million pounds of herbicides are produced domestically, of which approximately 70 percent is exported. Most of the exports go to Canada, Brazil, and Argentina. Other uses are optical brighteners and dyes (Chemical and Engineering News, July 26, 1976). Worldwide demand for cyanuric chloride was approximately 95,000 metric tons in 1975; capacity, 130,000 metric tons. Capacity is expected to grow to 170,000 metric tons worldwide in the next few years, with demand growing at 7.5 percent annually.

About 35,000 tons of HCN (16.5 percent of the total) went to domestic cyanuric chloride production in 1977. This use of HCN can be expected to increase with herbicide demand in the future.

Chelating Agents -- Six producers produced 170 million pounds of chelating agents in 1977, consuming 26.5 thousand tons of HCN (12.5 percent of the total). Markets for chelates include metal cleaning, textile processing, soaps and cleaning formulations, and industrial water treatment. Demand growth for chelates is expected to be moderate (about seven percent per year).

Sodium Cyanide -- Twenty thousand tons of HCN were used in the production of sodium cyanide in 1977. Sodium cyanide is used in the heat treatment of steel, extraction of gold and silver, electroplating of metals, and as a raw material in the manufacture of plastics. There is only one domestic manufacturer of sodium cyanide, and the required HCN is captively produced. Demand growth is expected to be low -- 3.5 percent per year -- but because sodium cyanide production represents only a fraction of total HCN use, it is of little significance.

TABLE 5-2

PRODUCERS OF METHYL METHACRYLATE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
CY/RO Industries	Fortier, LA	40	7.2	Hydrogen Cyanide	*
DuPont	Belle, W. VA	60	10.9	Hydrogen Cyanide	*
	Memphis, TN	120	21.8	Hydrogen Cyanide	*
Rohm & Haas	Houston, TX	330	60.0	Hydrogen Cyanide	*
TOTAL		550	100.0		

SOURCE: Chemical Marketing Reporter, April 13, 1976.

*Wide variety of end products.

Synthetic Methionine and Other Uses -- Two and one-half thousand tons of HCN went into synthetic methionine production in 1977. Ninety-five percent of the methionine is used in poultry feed. Domestic production supplied only 40 to 50 percent of the methionine consumed in the U.S. in 1977; imports made up the remainder. Other uses of HCN accounted for less than two percent of HCN use in 1977.

5.1.1.1.1 The Merchant Market

Less than 10 percent of all HCN produced is sold on the merchant market. Many industry sources believe the merchant market for HCN will disappear completely in five years, citing a general reluctance on the part of by-product HCN producers to market the HCN due to its toxicity. (Many by-product producers simply burn the HCN for fuel at the plant site to circumvent disposal problems.) In light of the chemical's toxicity and low market potential (only small users currently are purchasing HCN) it is unlikely that there will ever be a substantial merchant market for HCN.

5.1.1.2 Demand Summary

Table 5-3 summarizes the end uses for HCN and provides estimates of expected demand in 1984 based on the most likely rate of projected demand growth. The projected demand for HCN in MMA manufacture assumes that there will be no market penetration by the new technology ("C_4-oxidation") by 1984; however, if the C_4-oxidation production method does come on stream prior to 1984, a substantial amount of HCN could be displaced. This uncertainty is discussed further in Section 5.1.3.1.

5.1.2 Supply

5.1.2.1 Production

Hydrogen cyanide production was just under 198,000 short tons in 1977, 12 percent less than the peak of 226,000 tons in 1965. Production over

Table 5-3

CURRENT AND PROJECTED DEMAND FOR HCN BY USE

End Use	1977 Consumption of HCN (000 tons)	Projected Annual Growth Rate	Projected 1984 Demand
MMA	124.0	4.0%	163* (66)
Cyanuric Chloride	35.0	7.5	58
Chelating Agents	26.5	7.0	43
Sodium Cyanide	20.0	3.5	25
Other	6.5	4.0	9
TOTAL	212.0		298* (201)

* The first number is projected 1984 demand at a four percent growth rate and assumes that no "C_4 technology" MMA plants (which do not use HCN as a raw material) are built. The parenthesized number is a worst case estimate of 1984 demand. It assumes a slow market growth rate and some replacement of traditional-technology capacity with new technology plants. For a complete discussion of the uncertainties of the future MMA industry, see Section 5.1.3.1.

SOURCE: Department of Commerce and EEA Estimates the past decade has been variable (see Table 5-4 and Graph 5-1), reflecting major changes in end use. Hydrogen cyanide is useful in its ability to upgrade other raw materials (by specific addition to carbon atoms). However, technical advances may render the use of HCN obsolete in the manufacture of certain products, particularly methyl methacrylate. Production of HCN can be expected to decline somewhat over the next few years depending upon the rate at which new technologies are adopted.

5.1.2.2 Producers

Hydrogen cyanide currently is produced at 12 plant sites by nine producers (see Table 5-5). Two plants account for 43 percent of industry capacity: a 92.5 thousand ton/year plant in Memphis, TN, operated by DuPont, and a 100 thousand ton/year plant in Houston, TX, operated by Rohm and Haas. Of the remaining 10 plants, eight are medium sized (10-55 thousand tons/year) and two are small.

There is considerable forward integration in HCN production; captive use has been estimated at greater than 90 percent. Most HCN (about 75 percent) is manufactured for captive use in MMA or cyanuric chloride. Many of the larger plants are part of integrated complexes.

The two major producers of MMA, DuPont and Rohm and Haas, are integrated backward to HCN. In addition, they are integrated forward to LUCITE®, PLEXIGLAS®, molding and extrusion powders, and surface coatings. The third producer, CY/RO Industries, is a joint venture of Cyanamid and Roehm GmbH (a German-based firm) and is supplied with HCN by American Cyanamid's Fortier, LA, plant.

Ciba-Geigy and Degussa are the only two producers of cyanuric chloride. Both are integrated backward to HCN, and Ciba-Geigy forward to herbicides. The Ciba-Geigy Andrussow process HCN plant, located in St. Gabriel, Louisiana, has a 45,000 ton/year capacity. Degussa recently began

TABLE 5- 4

PRODUCTION OF HYDROGEN CYANIDE*

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1968-77		3.0%		
1968	152.2		NA	NA
1969	184.8	21.5	NA	NA
1970	160.5	-13.2	NA	NA
1971	140.7	-12.3	NA	NA
1972	135.8	- 3.5	NA	NA
1973	161.1	18.7	NA	NA
1974	175.8	9.1	NA	NA
1975	150.9	-14.2	NA	NA
1976	182.2	20.8	NA	NA
1977	197.9	8.6	NA	NA

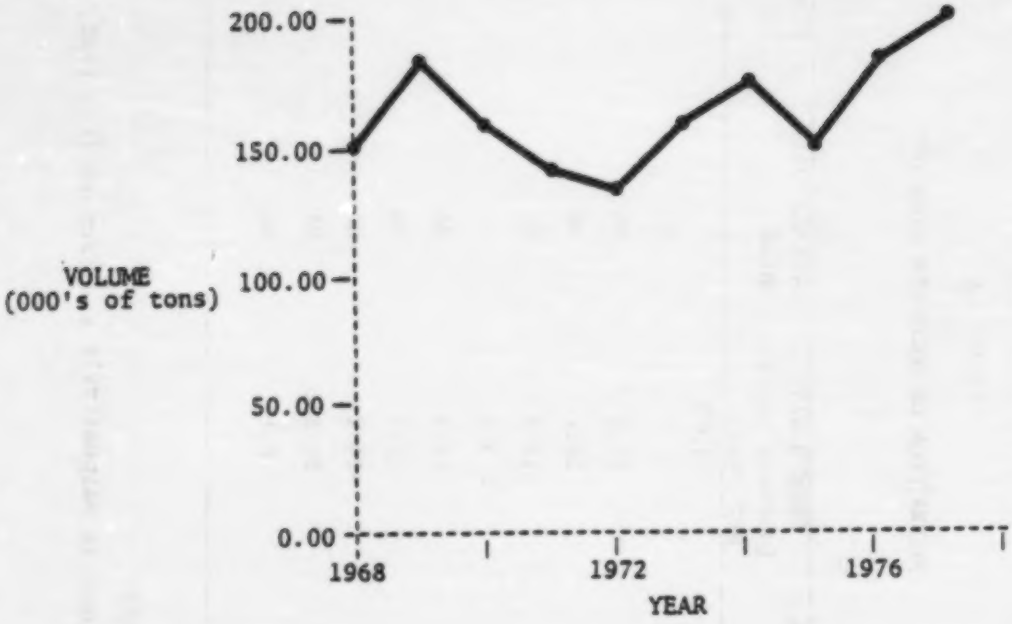
SOURCE: Department of Commerce.

*Excludes production of HCN used in adiponitrile manufacture (see text, Section 5.1).

NA = Not Available.

GRAPH 5-1

HYDROGEN CYANIDE PRODUCTION



SOURCE: Department of Commerce

TABLE 5-5

HYDROGEN CYANIDE PRODUCERS

COMPANY	LOCATION	PROCESS*	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
					RAW MATERIALS	END PRODUCTS
DuPont[1/]	Memphis, TN	Primary	92.5	20.8	Ammonia	Methyl Methacrylate
		Byproduct	20	4.5	Sulfuric Acid	
	Beaumont, TX	Byproduct	24	5.4	Acrylonitrile	Potassium Cyanide
Rohm & Haas	Houston, TX	Primary	100	22.5	Sulfuric Acid	Methyl Methacrylate
Monsanto	Alvin, TX	Byproduct	51.5	11.6	Acrylonitrile	Not Producing
	Texas City, TX	Primary	37.5	8.4	Ammonia Sulfuric Acid	Acetone Cyano-Hydrin (merchant**)
Vistron	Lima, OH	Byproduct	20	4.5	Acrylonitrile	Merchant
American Cyanamid	Fortier, LA	Byproduct	16	3.6	Acrylonitrile	Methyl Methacrylate
Ciba-Geigy	St. Gabriel, LA	Primary	45	10.1		Cyanuric Chloride
Degussa	Mobile, AL	Primary	26.5	6.0		Cyanuric Chloride Methianine
Hercules	Glen Falls, NY	Primary	1.5	0.3	Ammonia	
Dow	Freeport, TX	Primary	10	2.2	Ammonia	Chelates
TOTAL			444.5	100.0		

1/ In addition, DuPont operates two adiponitrile plants which have a combined capacity of 210,000 tons per year.

* Only primary process plants are affected by effluent regulations.

** Sold to one methyl methacrylate manufacturer.

SOURCE: Chemical Marketing Reporter, November 15, 1976 and Industrial Chemicals.

operation of its 26.5 thousand ton/year capacity HCN plant in Mobile, Alabama. Construction of these plants was undertaken to ensure supply in the face of what the cyanuric chloride producers perceived as an uncertain HCN supply situation.

HCN production by MMA manufacturers will decline in the next 5-10 years as they adopt the new MMA technology (see Section 5.1.3.1). No HCN capacity expansions currently are planned by the cyanuric chloride producers; however, rapid industry growth may prompt expansion.

5.1.2.3 Process

Most hydrogen cyanide (about 70 percent) is produced by a method known as the Andrussow process. The remaining HCN is produced as a by-product in acrylonitrile manufacture.

In the Andrussow process, air, ammonia, and natural gas are passed over a platinum or platinum rhodium catalyst and heated to 900 to 1000°C. The resulting hot gas stream contains hydrogen cyanide and several by-products, including hydrogen and carbon dioxide. The gas mix is cooled, stripped of unreacted ammonia, then routed to a cold water boiler where HCN is recovered. It is then distilled to a 99+ percent purity product. The reaction is:

$$2CH_4 + 2NH_3 + 3O_2 \rightarrow 2HCN + 6H_2O$$

The major pollutants in the waste stream are cyanides (both free and complex), ammonia, and ammonia salts. There are approximately 2.8 pounds of cyanides and 3.6 pounds of ammonia and ammonia salts for each ton of hydrogen cyanide produced. Some producers treat the wastewater by addition of chlorine which oxidizes the cyanides, but this method is not always successful. More reliable wastewater treatment systems are under development.

Table 5-6 shows the estimated costs of manufacturing one ton of hydrogen cyanide. Fixed investment, between $500 and $600 per ton of capacity, is fairly high. (Capital costs in inorganic chemicals manufacture range from 300 dollars per ton to 1500 dollars per ton, depending on the chemical produced and the process used.) Manufacturing costs are dependent on the cost of ammonia and natural gas which together account for about 50 percent of manufacturing costs.

Production of acrylonitrile, the source of by-product HCN, has grown rapidly (9.2 percent per year from 1971 to 1976). However, HCN production by this method will be moderated by two factors. First, the production process is continually being improved so that there is a greater acrylonitrile yield and a smaller by-product HCN yield. Whereas the process previously produced 0.15 to 0.20 kg of HCN for each kg of acrylonitrile, recent technological advancements can reduce this yield to as little as 0.07 kg per ton of acrylonitrile. Second, demand growth for acrylic, acrylonitrile's major end use, may be as low as two to three percent annually according to industry forecasts. Thus, this source of by-product HCN will probably decline significantly in the next five years.

By-product HCN is produced by oxidation of a propylene-ammonia mixture:

$$2CH_2 = CHCH_3 + NH_3 + 3O_2 \rightarrow 2\ CH_2 = CHCN + 6H_2O$$

Both hydrogen cyanide and acetonitrile are formed as by-products. There is no wastewater produced in this process.

5.1.3 Competition

A producer in any industry faces a number of sources of competition:

- Competition from other manufacturers of the product
- Import competition
- Competition from similar products which may serve as substitutes

In the case of hydrogen cyanide, with more than 90 percent of production used captively, manufacturers view the end products as the profit center.

If a less expensive input or process is found for the main product, then discontinuing the manufacture of the input product may be economical. Because hydrogen cyanide is an "upstream" product, competition at the end product level (i.e., MMA, cyanuric chloride, etc.) is the most critical factor. This section addresses competition in HCN's major end use markets, MMA and cyanuric chloride, which together account for three-fourths of HCN's use.

5.1.3.1 Methyl Methacrylate End Markets

There are currently three producers of MMA in the U.S. Domestic demand was about 350,000 tons in 1977. Of this, 80 percent was used captively by the manufacturer in the production of acrylic sheet and surface coatings. Most of the competition takes place in the acrylic sheet end market; but because of high profitability, MMA producers also compete vigorously for the relatively small merchant market share.

Industry capacity has risen in the last few years. Two of the three producers made significant capacity expansions in 1977: Rohm and Haas added 55,500 tons/year in Houston, Texas, and DuPont doubled its Memphis, Tennessee plant capacity to 120,000 tons/year. Capacity currently stands at 550,000 tons/year. Capacity utilization was about 80 percent in 1976, but somewhat lower in 1977 (about 68 percent) as the new capacity came on line.

There are no substitutes for MMA in the production of acrylic sheet or molding and extrusion powders. Several differentiated acrylic products are manufactured with special features to meet the specialized needs of consumers. For example, one grade of acrylic sheet is formulated so that it has a non-reflective surface. Another grade has three to four

TABLE 5-6a

ESTIMATED COST OF MANUFACTURING HYDROGEN CYANIDE - ANDRUSSOW PROCESS*
(mid-1978 dollars)

Plant Capacity	56,500 tons/year
Annual Production	35,000 tons/year (62% capacity utilization)
Fixed Investment	$34.8 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ammonia	2099 lb	0.065	136.40
- Natural Gas	63.9 mscf	1.50	95.90
- Sulfuric Acid (66 Be´)	960 lb	0.016	15.40
- Phosphoric Acid	17 lb	0.20	3.40
- Sulfuric Dioxide	0.8 lb	0.074	0.06
- Ammonium Sulfate Credit	1288 lb	0.02	(25.80)
- Catalyst			9.80
• Utilities			
- Electric Power	998 kWh	0.03	29.90
- Cooling Water	141 mgal	0.10	14.10
- Exhaust Steam Credit	1.29 mlb	3.25	(4.20)
Total Variable Costs			$275.00
SEMI-VARIABLE COSTS			
• Labor			12.40
• Maintenance			45.00
Total Semi-Variable Costs			$ 57.40
FIXED COSTS			
• Plant Overhead			3.10
• Depreciation			90.00
• Taxes & Insurance			13.50
Total Fixed Costs			$106.60
TOTAL COST OF MANUFACTURE			$439.00

SOURCE: Contractor and EEA estimates

---

*See Appendix C

TABLE 5-6b

ESTIMATED COST OF MANUFACTURING HYDROGEN CYANIDE - ANDRUSSOW PROCESS*
(mid-1978 dollars)

Plant Capacity	90,500 tons/year
Annual Production	56,000 tons/year (62% capacity utilization)
Fixed Investment	$48.4 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ammonia	2099 lb	0.065	136.40
- Natural Gas	63.9 mscf	1.50	95.90
- Sulfuric Acid (66 Be´)	960 lb	0.016	15.40
- Phosphoric Acid	17 lb	0.20	3.40
- Sulfuric Dioxide	0.8 lb	0.074	0.06
- Ammonium Sulfate Credit	1288 lb	0.02	(25.80)
- Catalyst			9.80
• Utilities			
- Electric Power	998 kWh	0.03	29.90
- Cooling Water	141 mgal	0.10	14.10
- Exhaust Steam Credit	1.29 mlb	3.25	(4.20)
Total Variable Costs			$275.00
SEMI-VARIABLE COSTS			
• Labor			10.10
• Maintenance			39.00
Total Semi-Variable Costs			$ 49.10
FIXED COSTS			
• Plant Overhead			2.50
• Depreciation			78.20
• Taxes & Insurance			11.70
Total Fixed Costs			$92.40
TOTAL COST OF MANUFACTURE			$416.50

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 5-6c

ESTIMATED COST OF MANUFACTURING HYDROGEN CYANIDE - ANDRUSSOW PROCESS*
(mid-1978 dollars)

Plant Capacity	113,000 tons/year
Annual Production	70,000 tons/year (62% capacity utilization)
Fixed Investment	$56.5 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ammonia	2099 lb	0.065	136.40
- Natural Gas	63.9 mscf	1.50	95.90
- Sulfuric Acid (66 Be´)	960 lb	0.016	15.40
- Phosphoric Acid	17 lb	0.20	3.40
- Sulfuric Dioxide	0.8 lb	0.074	0.06
- Ammonium Sulfate Credit	1288 lb	0.02	(25.80)
- Catalyst			9.80
• Utilities			
- Electric Power	998 kWh	0.03	29.90
- Cooling Water	141 mgal	0.10	14.10
- Exhaust Steam Credit	1.29 mlb	3.25	(4.20)
Total Variable Costs			$275.00
SEMI-VARIABLE COSTS			
• Labor			8.30
• Maintenance			36.60
Total Semi-Variable Costs			$ 44.90
FIXED COSTS			
• Plant Overhead			2.10
• Depreciation			73.10
• Taxes & Insurance			11.00
Total Fixed Costs			$86.20
TOTAL COST OF MANUFACTURE			$406.10

SOURCE: Contractor and EEA estimates

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*See Appendix C

times the impact strength of general purpose acrylic sheet and is aimed at the personnel and property protection market. Prices for the different grades of acrylic sheet vary according to the degree of product specialization.

Substitutes for acrylic sheet include glass and polycarbonates. Glass is heavier than acrylic sheet and breakable, but it is of better optical quality and scratch resistant. Acrylic sheet is used instead of glass in cases where strength is desirable. Its use in high rise buildings as an alternative to glass has not been as widespread as the industry anticipated. (Instead of acrylic sheet being used throughout the building, it is often used only on the ground floors, where there is a high risk of glass breakage.) Polycarbonates are making inroads into the acrylic sheet market, but are more expensive and less weatherproof.

Historically, competition in the MMA merchant market has been on the basis of price. A small import share (approximately 10 percent) has been responsible for downward pressure on domestic prices. The threat of import penetration is of major concern to domestic MMA producers, but they have maintained their market share by meeting low import prices.

Competition in the MMA industry will increase in the next five to 10 years as new "C_4-technology" plants come on line. If Oxirane's 300 million lbs/year plant comes on line in 1981 as planned, overall capacity utilization will remain at a low 70 percent. If demand should grow only two percent annually, as some analysts predict, capacity utilization will plunge to 61 percent. If another company builds a new MMA plant (both Rohm and Haas and Vistron have tentative plans), the mid-1980's are likely to see firms competing fiercely for market share (Chemical Engineering, July 3, 1978).

A number of Japanese and European manufacturers also are considering building new technology MMA plants. Japanese producers have begun to import HCN to cover demand shortfalls caused by a decrease in by-product HCN production. This gives them additional incentive to adopt the new MMA technology which may lower costs. The added cost advantage could mean a larger share of the U.S. MMA market for Japanese products. To retain market share, U.S. producers would be forced either to lower MMA prices to meet import competition, thereby reducing profit margins, or to make a more rapid shift to the new MMA technology.

Table 5-7 illustrates how an industry shift to the new C_4 technology will affect MMA industry competition, and, ultimately, HCN production levels. Because industry estimates of demand growth vary widely, two possible scenarios, which assume extreme rates of market growth, are examined. In scenario A, demand grows at seven percent, and capacity jumps to 1,700 million lbs/yr by 1984 as both Oxirane and Rohm and Haas bring on the new technology plants. Oxirane plans to sell 100 percent of their MMA, and if they successfully penetrate the MMA merchant market, could edge out the other producers. Some firms would be forced to reduce capacity.

In scenario B, MMA demand grows at a modest 2 percent annually. This means that even if Oxirane were to capture 100 percent of the merchant market, they could only operate at 76 percent capacity. If a second new technology plant were to come on line by 1984, some plants surely would be forced to shut down. These shutdowns most likely would occur in older, acetone cyanohydrin plants which utilize HCN. If the new plants were to operate at 76 percent of capacity, demand for HCN from MMA products would drop to 66 thousand tons in 1984, a reduction of 46 percent from 1977 levels. This implies that total demand for HCN in 1984 would drop by five percent from 1977 levels. In any event, scheduled construction of the new technology MMA plants is likely to reduce the demand for HCN. Within 10 to 15 years, HCN demand from MMA production should be near zero.

5.1.3.2 Cyanuric Chloride End Markets

The two domestic producers share a patent on the process for manufacturing cyanuric chloride. This eliminates inter-producer competition. Industry sources expect rapid growth in the number of producers when the patent expires in the near future.

There are no substitutes for cyanuric chloride in triazine herbicide manufacture. The triazine herbicides experience little competition from substitutes due to the product's high effectiveness and low toxicity.

5.1.4 Economic Outlook

5.1.4.1 Revenue

Total revenue is the product of total sales volume and the average unit price. Although these two variables are discussed separately below, they are interrelated.

5.1.4.1.1 Quantity

The production volume of hydrogen cyanide depends on the production levels of its end use products, and on the production of acrylonitrile, which produces HCN as a by-product. While growth can be expected for each of these end product chemicals, there are factors which may cause overall primary HCN production to decline. On the positive side:

- MMA is an important chemical with many end uses. MMA production should grow at least as rapidly as the rest of the economy.
- Cyanuric chloride is a high growth chemical. Industry capacity is likely to grow as new producers enter the triazine herbicide industry; increasingly favorable trade conditions will continue to expand markets.

On the negative side, use of HCN in MMA manufacture eventually will be eliminated by use of the new C_4-oxidation technology. The rate of new process adoption will determine the rate of HCN decline. The rate of

Table 5- 7

FUTURE MMA DEMAND AND CAPACITY

SCENARIO A
SEVEN PERCENT ANNUAL MMA DEMAND GROWTH

Year	MMA Demand (total) (MM lb/yr)	Resulting HCN Demand (M tons)	Merchant MMA Demand (MM lb/yr)	MMA Capacity (MM lb/yr)	Capacity Utilization	Capacity if CU = .75
1977	744	124	200	1,100	.67	*
1981	975	138	262	1,400	.70	1,300
1984	1,194	149	321	1,700	.70	1,592
SCENARIO B TWO PERCENT ANNUAL MMA DEMAND GROWTH						
1977	744	124	200	1,100	.67	*
1981	805	98	216	1,400	.58	1,073
1984	855	66	230	1,400	.61	1,140

SOURCE: EEA Estimates

adoption depends on the success of the first domestic new technology plant (scheduled for 1981 startup), competition from imports, and the need for capacity additions based on MMA demand growth.

Demand growth in acrylonitrile, the source of by-product HCN, has slowed, causing overcapacity, over-supply, and a halt in capacity expansions. In addition, technology improvements already have reduced HCN yield per pound of acrylonitrile and further advances are likely.

The net result of these influences will be a decline in total HCN production. The cyanuric chloride industry will become the largest user of HCN. New entrants into the cyanuric chloride industry may find it economical (as the existing producers have) to build small to medium size primary HCN facilities. In the long run, this may give rise to a new generation of Andrussow process plants.

5.1.4.1.2 Price

Because the merchant market for HCN is of such small consequence and, in fact, likely to disappear altogether in the next few years, a discussion of HCN price would be superfluous. Cyanuric chloride is sold by one producer to one buyer (Degussa to Shell Chemicals) so the details of that market are not available. MMA also is highly captive but, unlike HCN and cyanuric chloride there is a well developed market for the 15 to 20 percent of total production not used captively. The July 1978 list price was $.43/lb. MMA is highly profitable at this price, according to one industry source.

MMA prices are not likely to rise significantly in the next five years for a number of reasons:

- Growth in demand will be sluggish due to expected slow growth in the economy.
- Planned capacity additions will force competitive pricing by manufacturers in order for them to retain market share and keep capacity utilization at profitable levels.

- Imports will continue to constrain prices. More rapid adoption of the cheaper C_4 manufacturing technology by foreign MMA producers (due to acetone and HCN shortages they are experiencing) may allow import prices to stay uncomfortably low. The import price advantage may be augmented by recovery of the U.S. dollar on foreign exchange markets.

The existing profit margin may narrow in the future as input prices (tied to natural gas prices) rise faster than MMA prices.

5.1.4.2 Manufacturing Costs

5.1.4.2.1 Hydrogen Cyanide (Andrussow Process)

Ammonia, a natural gas product, and natural gas are the major inputs in HCN manufacture, and their prices have increased rapidly in the past few years. Manufacturing costs are linked closely to natural gas prices. The deregulation of natural gas prices is likely to stimulate gas supplies, but also guarantee future price increases. The cost of manufacturing HCN will continue to rise with natural gas prices.

5.1.4.2.2 Methyl Methacrylate

Raw materials in the acetone cyanohydrin route to MMA are acetone, hydrogen cyanide, and sulfuric acid. Acetone is a petroleum derivative, and its price will continue to increase with that of crude oil. However, acetone is manufactured as a by-product in phenol production and there have been recent large phenol capacity additions. This will serve to ensure acetone availability (Chemical Engineering, July 3, 1978).

The feedstock for MMA production by the new process (C_4 oxidation), isobutylene or tert-butyl alcohol, is cheaper than the feedstock used in the traditional process. The price of the feedstock will rise with petroleum prices. Manufacturers who are integrated backward to feedstock isobutylene or tert-butyl alcohol may have a significant cost advantage over feedstock purchasers.

5.1.4.2.3 Cyanuric Chloride

Cyanuric chloride uses HCN and chlorine as raw materials. Both of its producers are integrated backward to HCN, ensuring ample supply at a cost closely tied to natural gas prices. Chlorine prices will rise somewhat to reflect increased energy cost (chlorine is an energy intensive product with electricity as its major input).

5.1.4.3 Profit Margins

MMA will remain profitable even with a slowly growing economy. However, the adoption of the new technology will reduce the need for HCN.

Profits in the triazine herbicide industry (cyanuric chloride's major end use) currently are high, and industry spokesmen are optimistic that they will remain so. The high profits may attract new entrants to the industry — entrants who will require feedstock HCN. Cyanuric chloride will emerge as the most important of the remaining end uses for HCN, and the one with the greatest potential for growth.

5.1.5 Characterization Summary

Hydrogen cyanide is produced captively, primarily for use in:

- Methyl methacrylate (MMA), an intermediate in plastics;
- Cyanuric chloride, used in the manufacture of herbicides, and
- A number of other chemicals, which include chelating agents, sodium cyanide, and synthetic methenine.

Despite a reasonably strong overall demand outlook for the end product, hydrogen cyanide production will decline. This is because a new, less costly MMA production process has been developed which does not require HCN. As MMA manufacturers complete construction of new technology plants, their captive production of HCN will fall.

Of HCN's other end markets, cyanuric chloride has the greatest potential for growth. The projected 8 to 10 percent annual demand growth will partially offset reductions in HCN demand in the MMA market.

5.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the hydrogen cyanide subcategory to comply with BAT effluent control standards. The technical contractor has designed and estimated the cost of effluent control technologies to achieve these standards. The cost of the technology is used to make an assessment of the economic impacts that BAT control levels will have on the subcategory. Only primary process hydrogen cyanide producers are covered by proposed regulations.

All but one of the primary process hydrogen cyanide manufacturers are direct dischargers. A survey by the technical contractor revealed that all direct dischargers and the one indirect discharger have BPT treatment in place. This analysis assesses the additional costs required for direct dischargers to meet higher effluent removal levels. For the single indirect discharger, PSES guidelines are based on BPT treatment and, accordingly, will require no additional control costs for compliance with pretreatment regulations.

5.2.1 Pollution Control Technology and Costs

Capital and operating costs were developed by the technical contractor for pollution control technologies designed to meet BPT and BAT waste removal.

The two major pollutants in this subcategory are cyanide compounds and ammonia. In the model HCN plants, wastewater is assumed to contain an average of 2.8 pounds of cyanides and 3.6 pounds of ammonia per ton of manufactured HCN.

BPT treatment involves the following procedure:

- Wastewater is collected in an eight hour detention pond.
- Caustic soda and chlorine are added to the wastewater to neutralize the acid and oxidize the cyanide.
- The overflow goes to a one hour pond where additional chlorine and caustic soda are added before final discharge.

BAT treatment includes two additional steps:

- Additional chlorine is used to remove cyanide.
- The wastewater is then dechlorinated.

Pollution control cost estimates were developed for three sizes of model hydrogen cyanide plants. Model plant production rates are 35,000, 56,000 and 70,000 tons per year. All model plants use the Andrussow process, since by-product production during acrylonitrile manufacture produces no wastewater. Table 5-8 summarizes pollution control costs for the model plants.

The costs of manufacturing HCN, estimated by a subcontractor, are $463.70, $439.70, and $428.30 per ton, for the small, medium, and large plants, respectively. These estimates are based on those presented in Table 5-6 and include the cost of meeting BPT effluent limitations. Table 5-9 summarizes the cost parameters used in the model plant analysis.

The total compliance costs for the hydrogen cyanide subcategory are summarized in Table 5-10. These costs are based on the model plant pollution control costs and current primary process production levels. All primary process hydrogen cyanide manufacturers have base level removal equipment in place. The total additional cost to the subcategory for compliance with BAT removal levels is estimated to be $713,489. As noted above, no additional costs are required for compliance with PSES regulations.

TABLE 5-8: POLLUTION CONTROL COSTS

Chemical: Hydrogen Cyanide

Model Plant Production (tons/year)	BPT/PSES		BAT*	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
35,000	$1,335,768	$ 577,050	$189,750	$146,268
56,000	2,079,588	854,546	204,930	205,241
70,000	2,481,822	1,024,237	288,420	245,595

*BAT costs represent incremental costs above BPT costs.

Source: Technical Contractor

TABLE 5-9: MANUFACTURING COSTS

Chemical: Hydrogen Cyanide

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs* Per Ton
35,000	$34,800,000	$463.70
56,000	48,380,000	439.70
70,000	56,500,000	428.30

*Includes the cost of meeting BPT effluent limitations.

Note: All costs are in mid-1978 dollars.

TABLE 5-10

SUBCATEGORY COMPLIANCE COSTS*

Chemical: Hydrogen Cyanide (Primary Process)

	BAT		
Model Plant Production (tons/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)
35,000	78,325	$ 948,750	$419,039
56,000	NA	NA	NA
70,000	65,000	288,420	294,450
TOTAL	143,325	1,237,170	713,489

* This table includes costs only for direct discharge primary process hydrogen cyanide plants. One indirect discharger is already meeting PSES regulations. The costs shown here represent incremental costs above BPT required for subcategory compliance with BAT regulations.

NA: Not applicable - no plants incurring costs.

5.2.2 Model Plant Analysis

This section outlines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

- Price Rise - the calculation of the price increase required to fully recover the increased pollution control costs.
- Profitability Decline - the maximum decline in profitability that would result if no price increase were possible.
- Price Elasticity of Demand - a subjective estimate based on information in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.
- The Capital Ratio - the ratio of pollution control capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

5.2.2.1 Price Rise Analysis

The price rise analysis assumes full pass-through of all pollution control costs. Table 5-11 summarizes the price increase required of each model plant for BAT removal. No more than a 0.81 percent price increase is required to pass through all the pollution control costs associated with BAT removal.

5.2.2.2 Profitability Analysis

The profitability analysis examines the decline in the return on investment (ROI) and internal rate of return (IRR) when no price pass-through is possible. For the purposes of the analysis, a market price of HCN was assumed to be $660/ton (Chemical Marketing Reporter, July 28, 1978). However, since HCN is predominantly produced for captive use, market price is somewhat artificial. Under these assumptions the hydrogen cyanide model plants had a decline in both the ROI and IRR of less than four-tenths of one percentage point representing a decrease in profitability of less than 1.5 percent. These results are summarized in Table 5-12.

5.2.2.3 Price Elasticity of Demand

Since most hydrogen cyanide is captively produced for use in various downstream products, the price elasticity of demand for this chemical is determined by the price elasticity of demand for its end products. About 60 percent of HCN goes to methyl methacrylate (MMA) production, which is used in acrylic sheet production. Another 15 percent is used to make cyanuric chloride which ultimately becomes triazene herbicide.

Demand for acrylic sheet is fairly strong, although somewhat dependent upon the construction industry. Acrylic sheet is the preferred material in many applications, despite the existence of a number of substitutes for acrylic sheet. This implies that demand is somewhat price inelastic and the manufacturer should be able to raise prices to cover increased HCN cost. However, domestic acrylic sheet manufacturers face competition from imports which could restrain prices.

Producers of cyanuric chloride are in an even stronger position to pass on a cost increase in higher prices. There are no real substitutes for end-product triazene herbicide. This implies a low price elasticity of demand for cyanuric chloride in the relevant price range. If HCN costs were to increase significantly due to effluent control regulations, cyanuric chloride producers would have little difficulty raising prices to cover these costs. Based on these factors, demand for HCN is assumed to be price inelastic. (See Sections 5.1.1, Demand and 5.1.3, Competition, for a complete analysis).

TABLE 5-11

PERCENTAGE PRICE RISE

Chemical: Hydrogen Cyanide

Price: $660/ton

Model Plant Production (tons/year)	BAT
35,000	0.81%
56,000	0.67%
70,000	0.69%

TABLE 5-12

PROFITABILITY CHANGE

Chemical: Hydrogen Cyanide

Level: BAT

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
35,000	22.37%	22.04%	-0.33% (-1.48%)	21.85%	21.58%	-0.27% (-1.24%)
56,000	25.91%	25.58%	-0.33% (-1.27%)	24.72%	24.46%	-0.25% (-1.01%)
70,000	27.87%	27.50%	-0.37% (-1.33%)	26.23%	25.96%	-0.27% (-1.03%)

5.2.2.4 Capital Analysis

End product demand and industry profits are high enough to warrant the investment of four-tenths to five-tenths of one percent of total fixed investment (see Table 5-13). The alternative to making the investment (i.e., shutting down) is more costly in the long run. All three producers are large, profitable chemical companies and should have little difficulty raising capital.

5.2.2.5 Closure Analysis

Table 5-14 summarizes the price elasticity of demand, price rise, and profitability decline for hydrogen cyanide model plants and compares these to EPA's closure criteria (see methodology description). Since most hydrogen cyanide is produced for captive use, demand is price inelastic for all model plants. The required price increase is less than one percent for all model plants. The potential profitability decline does not exceed one percentage point, or ten percent of baseline profitability for any of the models. Based on the EPA's closure criteria, no plant closures are forecast.

5.2.3 Industry Impacts

In this section, the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on hydrogen cyanide manufacturers.

5.2.3.1 Price and Profitability Impacts

The increase in the production cost of HCN due to BAT treatment is no more than 0.81 percent for all model plant sizes (see Table 5-11). Manufacturers should have little trouble passing this cost increase through to consumers of downstream products.

One way of placing this increase in perspective is to compare it with an increase in the price of one of HCN's raw materials. A five percent increase in the price of natural gas (from $1.50 per 1000 cubic feet to $1.58 per 1000 cubic feet) would increase HCN's manufacturing cost by $5.11/ton. This is approximately equivalent to a one percent cost increase that would result from pollution control cost.

Another method of assessing the impacts of an HCN price increase is to evaluate the effects on end product prices. The magnitude of price increases in downstream products will depend on the quantity of HCN used in their manufacture. One ton of MMA requires 0.27 tons of HCN at a cost of $178 (0.27 tons of HCN at $660/ton). The additional cost of HCN wastewater treatment would raise this cost to roughly $180 (0.27 tons of HCN at the new cost of $665/ton). Therefore, MMA manufacturers would need to raise the price of merchant MMA 0.32 percent in order to keep profits constant. Assuming a production cost of $620/ton for MMA, the cost increase would be $2.00.

Dealing with a one time cost increase of less than one percent should present no problem to an industry that successfully has dealt with quickly rising costs in the past. The profit outlook for both MMA and cyanuric chloride is sound. MMA producers have raised prices by 120 percent since 1973 to offset increased energy costs. Producers will be able to raise prices by the small amount necessary to cover pollution control costs.

Should producers be unable to pass on the higher costs of effluent control to consumers, the resulting profitability decline, as measured by the change in IRR and ROI, would be negligible.*

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* This cash flow analysis assumed that HCN was manufactured in a self-standing plant, and acted as a profit center. Since HCN is a captive, intermediate product, this is not the case. However, this assumption was made in order to gauge the "profitability" decline.

TABLE 5-13

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Hydrogen Cyanide

	Model Plant Production (tons/year)		
Level of Removal	35,000	56,000	70,000
BAT	0.5%	0.4%	0.5%

TABLE 5-14

IMPACT SUMMARY

Chemical: Hydrogen Cyanide

	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
CLOSURE CRITERIA DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater Than 10% of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE (% DECLINE)	CLOSURES
BAT	35,000	Low	0.81%	0.27% (1.24%)	no
	56,000		0.67%	0.25% (1.01%)	no
	70,000		0.69%	0.27% (1.03%)	no

SOURCE: EEA estimates.

The change in profitability (IRR) is less than three-tenths of one percentage point, or less than 1.3 percent from the base case, for each model plant size. The small profitability decline indicates that MMA producers will not have increased incentive to replace existing MMA plants with new technology plants to reduce HCN production.

5.2.3.2 Other Impacts and Conclusion

Because the price and profitability impacts are small, the hydrogen cyanide subcategory will not suffer severe impacts from BAT effluent control costs. Therefore, all other impact areas (plant closures, employment, communities, etc.) will be unaffected.

6. HYDROGEN FLUORIDE

6.1 CHARACTERIZATION

Hydrogen fluoride (HF) or hydrofluoric acid, is a very reactive inorganic acid used to fluorinate both organic and inorganic molecules. Its principal uses are (1) in the production of aluminum fluoride where, together with cryolite, it forms a molten electrolyte for aluminum reduction, and (2) as a reagent in the formation of chlorofluorocarbons ("fluorocarbons") which serve primarily as solvents, blowing agents, and refrigerants. In addition, hydrogen fluoride is used in stainless steel pickling, uranium processing, petroleum alkylation, and several other smaller applications.

Hydrogen fluoride is not an end use commodity. It functions as an input in the production of other goods. As such, demand for HF is determined largely by the profitability, growth, and current production technology of its end use markets. Changes in these variables have had a severe impact on the hydrofluoric acid market over the last four years, and considerable uncertainty remains concerning the product's future. This characterization will examine the manufacturing cost outlook for hydrofluoric acid, the strengths and weaknesses of its end use markets, and potential changes in demand.

6.1.1 Demand

Hydrogen fluoride has two main end uses, primary aluminum production, and fluorocarbons production. The most recent statistics indicate that these uses accounted for 27 percent and 39 percent of total HF production, respectively. In addition to these functions, HF is used in approximately 10 other end markets, each accounting for one percent or more of total production. Among the most significant of these are stainless steel and exotic metals processing, uranium fuels processing, and petroleum alkylation. A breakdown of end uses for HF can be found in Figure 6-1.

In order to depict the total demand for hydrogen fluoride, the conditions in the individual end markets are summarized below.

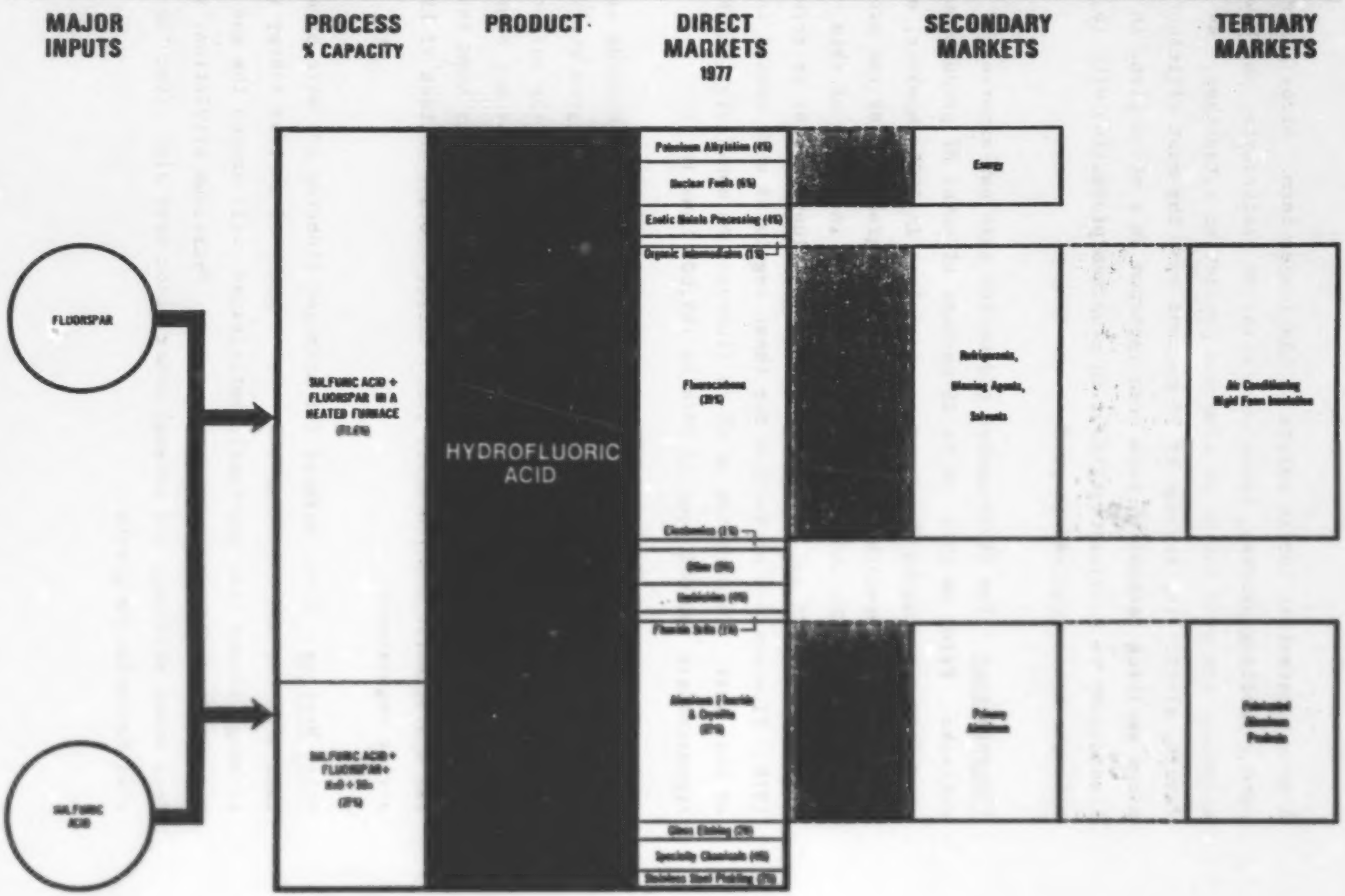
6.1.1.1 End Markets

Aluminum - There have been severe forces acting on the two primary end use markets for HF. The aluminum market has been hardest hit, with HF consumption dropping from a high of 166,900 tons in 1974 to just 91,260 tons in 1977. This drop is a result of extensive fluoride recovery efforts by the aluminum manufacturers, and a seven percent reduction in total aluminum output in 1977 as compared to 1974. Recovery efforts were precipitated in part by the economic advantages of recovering cryolite and sodium fluoride from solid waste and in part by fluoride emission guidelines imposed by EPA.

Hydrofluoric acid demand in aluminum production is expected to continue declining, but at a much more moderate pace. Fluoride recovery technology, with its consequent reduction in HF demand, is not yet fully operational in some aluminum smelting plants. Thus, further reductions can be expected when the equipment comes on line. In addition, HF producers cannot expect an increase in aluminum ingot capacity to bolster the market. Aluminum producers were hurt in the early 1970's and in 1975 by expanding capacity too rapidly. In the face of a strong aluminum market in 1978 they reduced expansion in order to support higher prices and increase return on equity. Additionally, long-term power contracts, considered essential to investment in new capacity, are becoming increasingly difficult to negotiate. Thus, short-term growth prospects for HF in the aluminum end market are poor.

FIGURE 6-1

HYDROFLUORIC ACID :
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
TERTIARY MARKETS
FLUORSPAR
SULFURIC ACID
SULFURIC ACID + FLUORSPAR IN A HEATED FURNACE ([illegible])
SULFURIC ACID + FLUORSPAR + H_2O + SO_3 ([illegible])
HYDROFLUORIC ACID
Petroleum Alkylation (4%)
Nuclear Fuels (6%)
Exotic Metals Processing (4%)
Organic Intermediates (1%)
Fluorocarbons (39%)
Electronics (1%)
Other (5%)
Herbicides (4%)
Fluoride Salts (1%)
Aluminum Fluoride & Cryolite (27%)
Glass Etching (2%)
Specialty Chemicals (4%)
Stainless Steel Pickling (2%)
Energy
Refrigerants,
Blowing Agents,
Solvents
Primary Aluminum
Air Conditioning
Rigid Foam Insulation
Fabricated Aluminum Products

A more substantial threat exists in the longer term. Alcoa has developed a smelting process, based on a chloride electrolyte, which would eliminate the need for HF in aluminum production altogether. As a result, electricity savings of 30 percent over the most efficient aluminum smelting technology have been reported at a pilot plant in Texas. Electricity is a major cost input in aluminum production with 16,000 kilowatt hours required to produce one ton.

Fluorocarbons - The fluorocarbon end market also has experienced severe cutbacks. Prior to 1975, 20 to 25 percent of total HF production was used in manufacturing fluorocarbon aerosols. In 1975, however, evidence showed that fluorocarbon gases could cause degradation of the protective ozone layer of the atmosphere, increasing the incidence of skin cancer. This prompted EPA and FDA to ban the use of fluorocarbons as aerosols in 1978. Fluorocarbon production for these regulated uses ceased in December of that year. Consumption of HF in fluorocarbon manufacturing fell from approximately 160,000 tons in 1974 to 109,000 tons in 1977.

Other fluorocarbon applications, such as refrigerants, blowing agents, and solvents, have remained strong and are expected to grow at five or six percent per year. This would certainly strengthen the market for HF. However, EPA is currently considering regulation of all fluorocarbon uses. No regulatory schedule has been announced at this time (summer 1981). The hydrofluoric acid industry could suffer another setback if EPA imposes strict regulations.

Other Markets - Other markets for hydrogen fluoride are more promising than aluminum and fluorocarbons. Development of nuclear energy sources, although slower than previously anticipated, will expand the use of hydrofluoric acid in uranium processing. Petroleum alkylation, stainless steel pickling, and several other minor uses also offer the potential for moderate growth.

6.1.1.2 Demand Summary

Demand for hydrogen fluoride has decreased substantially since 1974. The main reasons for this decline are summarized below:

- **The EPA and FDA ban on fluorocarbon aerosols has eliminated a major market for hydrofluoric acid.**
- **Fluoride recovery efforts by aluminum manufacturers have substantially reduced the consumption of cryolite and aluminum fluoride in aluminum production. Both of these products use HF as a starting material.**
- **Demand could be further weakened by the introduction of Alcoa's chloride reduction technology (see Section 6.1.1.1), which would eliminate the need for fluoride electrolytes.**

Barring any further environmental regulation of fluorocarbon use such as for refrigerants and blowing agents, this market should grow five to six percent annually according to industry sources. The use of HF in petroleum alkylation and uranium processing is also growing. Overall predictions for HF consumption range from a continued decline to a growth rate of one to four percent.

6.1.2 Supply

6.1.2.1 Production

Hydrofluoric acid production grew at an annual compound rate of 4.9 percent between 1967 and 1974, reflecting growing demand for fluorocarbons and large expansions in aluminum production. Peak production of 381,005 tons was reached in 1974. During the years 1974 to 1977, sharply declining demand from the aluminum and fluorocarbon industries caused production to fall 27 percent, an annual compound rate of decline of 9.9 percent (see Table 6-1 and Graph 6-1). Domestic production should continue to decline slightly in the short-term, as fluoride recovery efforts continue in the aluminum industry.

In the longer term, production of HF will depend upon the status of further fluorocarbon regulation and development of Alcoa's new chloride reduction technology. Strict regulation and the elimination of fluorides as an electrolyte in aluminum production could severly impact the industry.

6.1.2.2 Producers

Presently there are six producers of hydrogen fluoride operating nine plants. Three producers, Allied, DuPont, and Alcoa account for 80 percent of capacity. HF capacity has diminished considerably since 1974 in response to decreasing demand. Current producers and facilities are illustrated in Table 6-2. Four plants have closed, and capacity has been reduced 31 percent from 398,000 tons/year to 274,000 tons/year. Two of these shutdowns occurred during December 1978 when Stauffer and Kaiser reduced their capacity by a combined total of 68,000 tons/year. Further closures can be expected if demand continues downward, and may occur even if demand stabilizes, as imports are offering increasing competition.

The majority of hydrofluoric acid is used captively. Alcoa uses it in the production of aluminum fluoride; DuPont, Allied, Essex, and Pennwalt in the production of fluorocarbons; and Harshaw in the production of fluoride salts. Some of the acid is sold to smaller consumers on a merchant basis, but this accounts for only a fraction of total output.

Backward integration is not as prevalent as forward integration. Fluorspar (generally imported) and sulfuric acid are the two major material inputs in HF production. Domestic production is low and the arsenic content of some domestic ores creates technical problems in fluorocarbon manufacturing. Major import sources are Mexico, Canada, Europe, and Africa.

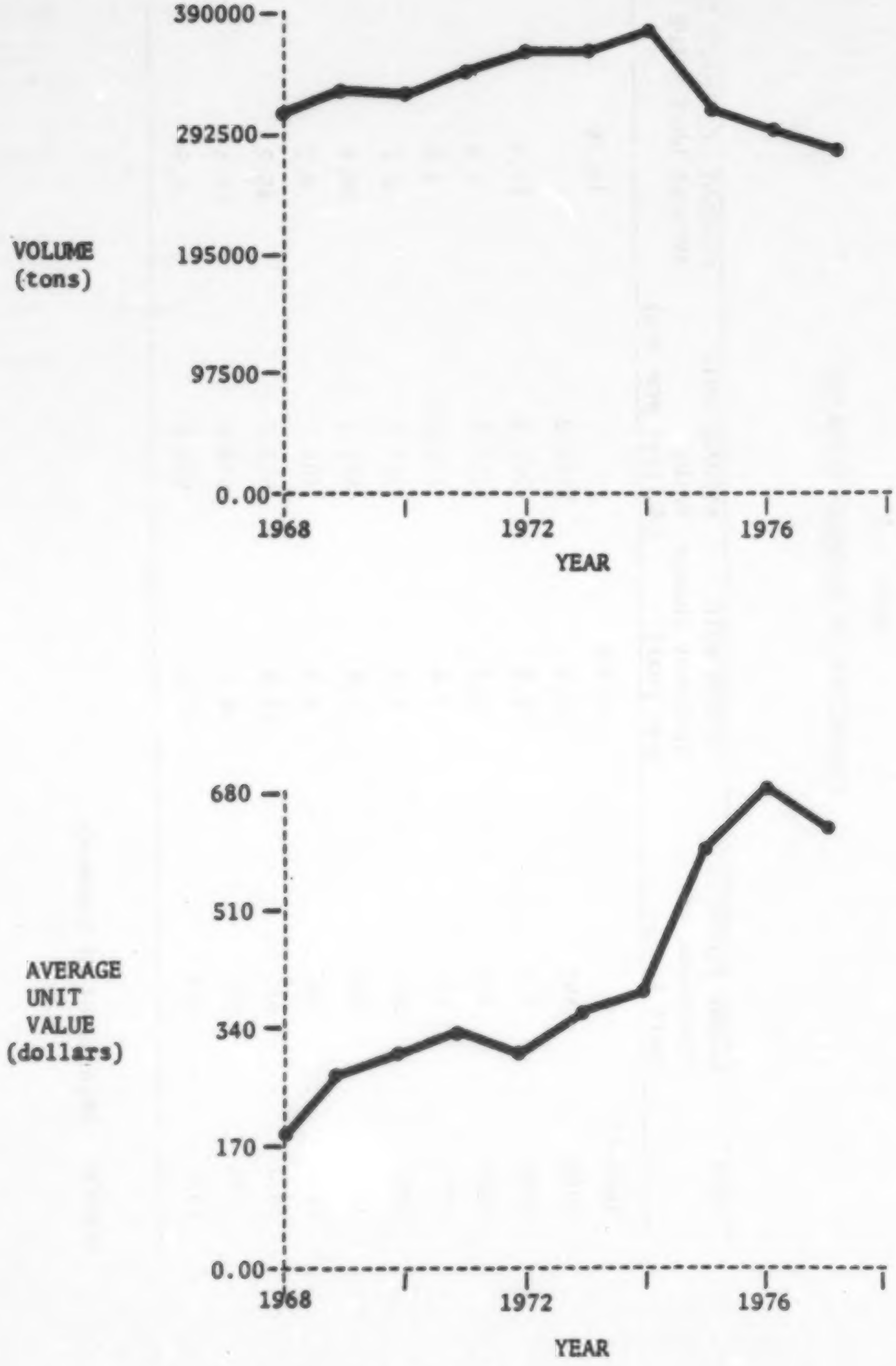
TABLE 6-1

PRODUCTION OF HYDROGEN FLUORIDE

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (dollars per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1968-77		-0.9%		14.7%
1968	302	10.6	$185.2	
1969	327	8.5	291.8	57.6
1970	325	-0.8	319.5	9.5
1971	334	2.8	338.3	5.9
1972	352	5.4	317.7	-6.1
1973	365	3.8	371.1	16.8
1974	381	4.3	401.7	8.2
1975	313	-17.8	583.2	45.2
1976	288	-8.1	668.5	14.6
1977	278	-3.4	635.9	-4.9

SOURCE: Department of Commerce.

GRAPH 6-1
HYDROGEN FLUORIDE PRODUCTION AND PRICE



SOURCE: Department of Commerce

TABLE 6-2

PRODUCERS OF HYDROGEN FLUORIDE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
Allied Chemical Corporation	Baton Rouge, LA Geismar, LA Nitro, W. VA Port Chicago, CA	90	32.8	Sulfuric Acid	Aluminum Fluoride Fluorocarbons
Aluminum Corporation of America (ALCOA)	Pt. Comfort, TX	55	20.1		Aluminum Fluoride
DuPont	Strang, TX	75	27.4	Sulfuric Acid Fluorspar	Fluorocarbons
Essex	Paulsboro, NJ	11	4.0	Sulfuric Acid	Fluorocarbons
Harshaw	Cleveland, OH	18	6.6		Fluoride Salts
Pennwalt	Calvert City, KY	25	9.1		Fluorocarbons
TOTAL		274	100.0		

SOURCE: Chemical Marketing Reporter and Contractor Estimates.

Some producers, such as DuPont, are integrated to fluorspar through interests in foreign subsidiaries. Many producers, however, buy fluorspar on the market. Allied, DuPont, and Essex are producers of sulfuric acid. The remaining three HF manufacturers purchase sulfuric acid commercially.

6.1.2.3 Process

Hydrofluoric acid is manufactured by the reaction of sulfuric acid and the mineral fluorspar (97 percent calcium fluoride) in a reaction vessel heated to between 200 and 250°C. Hydrogen fluoride is evolved as a gas, which is cleaned of dust and traces of sulfuric acid, then condensed. The condensed liquid is distilled to obtain 99.90 to 99.95 percent hydrofluoric acid. The process is governed by the following reaction:

$$CaF_2 + H_2SO_4 \rightarrow 2HF + CaSO_4$$

For each ton of HF, approximately 3.8 lb of calcium sulfate is formed as a by-product along with small amounts of fluosilicic acid. The fluosilicic acid can be used in water treatment, but is generally discarded with the calcium sulfate as landfill.

The reaction process is endothermic (requiring energy to drive the reaction) and the energy requirements represent a significant cost input in the production process.

DuPont has developed a variation of this process using the heat generated by the reaction of water and sulfur trioxide to drive the reaction between fluorspar and sulfuric acid. With the proper mix of inputs, no external heat source is required for the production of HF. The procedure is based on the following reaction:

$$2CaF_2 + H_2SO_4 + SO_3 + H_2O \rightarrow 2CaSO_4 + 4HF$$

Net heat of reaction is 0.

Estimated material requirements and costs for the standard HF production process are found in Table 6-3.

6.1.3 Competition

The domestic hydrogen fluoride industry serves primarily captive end markets. The producers are large aluminum, chemical, and diversified firms. There is no domestic competition for this segment of the market because these firms supply their own needs. There is some price competition in the merchant market. Its degree, however, is moderated by the fact that hydrofluoric acid is a chemical reagent, or building block, fundamental to many processes. This accounts for the long-term contracts and stable supply sources which characterize the market.

Few substitutes for HF threaten its market position in any of its primary applications. However, hydrofluoric acid does face stiffening competition from imports, which have several advantages. The majority of imported HF comes from Mexico, where DuPont opened a 75,000 tons/year plant in 1975. Mexico offers the advantages of large deposits of fluorspar and sulfur (the primary inputs in HF production), relatively cheap labor, and a tariff structure which places no duty on finished acid, yet taxes unfinished fluorspar, thus raising the costs of U.S. production.

6.1.4 Economic Outlook

An industry's profitability is the difference between total revenues and total costs. There are factors that influence these independently so it is therefore useful to present a revenue outlook and cost outlook separately.

6.1.4.1 Revenue

Total revenue is the product of quantity sold and average unit price. Although these two variables are discussed separately, they are interrelated.

6.1.4.1.1 Quantity

The outlook for domestic production and sale of hydrogen fluoride is, at best, one of stable or very slightly increasing volume. More likely, however, is a continuing decline in the quantity of HF produced and sold by the domestic industry. Several forces are acting to bring about this change. Among the most important are the following:

- Continuing fluoride recovery by domestic aluminum producers
- New aluminum smelting technology which eliminates the need for fluorides in aluminum production
- Potential regulation of all fluorocarbon uses including refrigerants and blowing agents for rigid foam insulation

Provided that the EPA does not invoke new fluorocarbon regulations, there are some promising aspects to the hydrofluoric acid market. The most important are:

- Uranium fuels processing for nuclear reactors
- Petroleum alkylation

Increases in these and other smaller markets may offset the continuing decline in HF and stabilize the market.

6.1.4.1.2 Price

The hydrogen fluoride market is highly captive. Integrated producers use it as an input in aluminum production, fluorocarbon manufacturing, and several smaller applications. In captive roles, the price of HF has little meaning, as the profitability of the entire production stream determines its value.

End uses which constitute the merchant market for HF (primarily uranium processing, petroleum alkylation, electronics, and stainless steel pickling) are strong and offer good growth potential. Thus, from a demand perspective, the merchant market appears able to sustain moderate price increases. However, falling demand for HF in captive uses may create an oversupply which could temporarily mitigate those increases. Sustained periods of excess capacity probably would bring further plant closures.

Competition from Mexican imports also could limit price increases. The threat of expanded production of Mexican HF could require price restraint by domestic producers.

6.1.4.2 Manufacturing Costs

Hydrofluoric acid production uses energy intensive inputs and requires process temperatures above 200°C for reaction. Thus, manufacturing costs will continue to rise with the cost of energy. In addition, the cost of sulfuric acid, one of the two material inputs, has risen at an annual compound rate of 18 percent since 1972. Sulfuric acid prices are not expected to stabilize, as it too is produced by an energy intensive process.

Price increases for fluorspar have been moderate by comparison. The price has increased at a compound annual rate of 5.4 percent per year from 1974 to 1979, which is low compared to price increases in the chemical industry as a whole.

The overall outlook is for costs to increase at a relatively brisk pace, primarily due to high process energy requirements. Estimated material requirements and costs can be found in Table 6-3.

6.1.4.3 Profit Margins

There are serious questions concerning the profitability of hydrofluoric acid production. If large decreases in demand occur due to EPA regulation or fluoride recycling by aluminum producers, excess capacity will force price competition and ultimately plant closures. In addition, imports from Mexico, which have some cost advantages (see Section 6.1.3), may force price restraint on the merchant market.

In the merchant segment of the market, demand increases are expected to provide support for future price hikes. This is based on the assumption that capacity will shrink if demand falls in the captive sectors, alleviating any oversupply situations. Price increases will be required to keep the merchant market profitable, as costs will continue increasing, particularly for energy inputs.

6.1.5 Characterization Summary

The hydrofluoric acid industry has changed substantially over the past five years. Production dropped 27 percent between 1974 and 1977, primarily due to fluoride recovery and recycling efforts in the aluminum industry, and the EPA and FDA ban on fluorocarbon aerosols. Further reductions may be forthcoming if the EPA decides to regulate all fluorocarbon uses, or if the aluminum industry accomplishes substantial further reductions in HF requirements.

Depending upon the resolution of the two issues mentioned above, growth in HF demand could range between a continued decline and growth of five or six percent.

Industry profitability will also depend, in large part, on the outcome of these two issues.

TABLE 6-3a

ESTIMATED COST OF MANUFACTURING HYDROGEN FLUORIDE*

(mid-1978 dollars)

Plant Capacity	25,400 tons/year
Annual Production	21,000 tons/year (83% capacity utilization)
Fixed Investment	$11.3 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Flurospar (97%)	2.17 tons	107.23	232.70
- Sulfuric Acid	1.5 tons	46.46	69.70
- 20% Oleum	1.09 tons	48.55	52.90
- Hydrated lime	.02 tons	32.50	0.70
• Utilities			
- Cooling water	18.86 mgal	.1	1.90
- Steam	.985 tons	6.50	6.40
- Process water	60 gal	.75	45.00
- Electricity	212 kWh	.03	6.40
- Natural Gas	4 MMBtu	2.50	10.00
Total Variable Costs			$425.70*
SEMI-VARIABLE COSTS			
• Labor			32.20
• Maintenance			15.50
Total Semi-Variable Costs			$ 47.70
FIXED COSTS			
• Plant Overhead			58.80
• Depreciation			53.80
• Taxes & Insurance			10.80
Total Fixed Costs			$123.40
TOTAL COST OF MANUFACTURE			$596.80

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 6-3b

ESTIMATED COST OF MANUFACTURING HYDROGEN FLUORIDE*
(mid-1978 dollars)

Plant Capacity	50,700 tons/year
Annual Production	42,000 tons/year (83% capacity utilization)
Fixed Investment	$18.4 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Flurospar (97%)	2.17 tons	107.23	232.70
- Sulfuric Acid	1.5 tons	46.46	69.70
- 20% Oleum	1.09 tons	48.55	52.90
- Hydrated lime	.02 tons	32.50	0.70
• Utilities			
- Cooling water	18.86 mgal	.1	1.90
- Steam	.985 tons	6.50	6.40
- Process water	60 gal	.75	45.00
- Electricity	212 kWh	.03	6.40
- Natural Gas	4 MMBtu	2.50	10.00
Total Variable Costs			$425.70*
SEMI-VARIABLE COSTS			
• Labor			19.00
• Maintenance			12.60
Total Semi-Variable Costs			$ 31.60
FIXED COSTS			
• Plant Overhead			45.80
• Depreciation			43.70
• Taxes & Insurance			8.70
Total Fixed Costs			$98.20
TOTAL COST OF MANUFACTURE			$555.50

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 6-3c

ESTIMATED COST OF MANUFACTURING HYDROGEN FLUORIDE*
(mid-1978 dollars)

Plant Capacity	76,100 tons/year
Annual Production	63,000 tons/year (83% capacity utilization)
Fixed Investment	$24.4 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Flurospar (97%)	2.17 tons	107.23	232.70
- Sulfuric Acid	1.5 tons	46.46	69.70
- 20% Oleum	1.09 tons	48.55	52.90
- Hydrated lime	.02 tons	32.50	0.70
• Utilities			
- Cooling water	18.86 mgal	.1	1.90
- Steam	.985 tons	6.50	6.40
- Process water	60 gal	.75	45.00
- Electricity	212 kWh	.03	6.40
- Natural Gas	4 MMBtu	2.50	10.00
Total Variable Costs			$425.70*
SEMI-VARIABLE COSTS			
• Labor			14.40
• Maintenance			11.10
Total Semi-Variable Costs			$ 25.50
FIXED COSTS			
• Plant Overhead			40.90
• Depreciation			38.60
• Taxes & Insurance			7.70
Total Fixed Costs			$87.20
TOTAL COST OF MANUFACTURE			$538.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

6.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the hydrogen fluoride subcategory to comply with BAT effluent control standards. The technical contractor has designed and estimated the cost of effluent control technologies required to achieve these standards. The cost of the technology is used to make an assessment of the economic impacts that BAT control levels will have on the subcategory.

A survey by the technical contractor revealed that all hydrogen fluoride manufacturers are direct dischargers having BPT treatment in place. Therefore, this analysis assesses the impact of only the additional costs required to meet BAT effluent removal levels.

6.2.1 Pollution Control Technology and Costs

Capital and operating costs have been developed by the technical contractor for pollution control equipment designed to meet BPT and BAT levels of waste removal.

The primary source of wastewater in hydrofluoric acid manufacture is kiln waste. Calcium sulfate is formed following the reaction of fluorspar and sulfuric acid. This waste is removed by means of a wastewater slurry. Approximately 3.8 pounds of solid calcium sulfate is generated in the rotary kiln per pound of product.

In addition to kiln waste, other sources of process waste are air pollution control equipment (scrubbers), leaks, spills and washdown. Scrubber waste flows depend upon plant operations and state and local air pollution regulations.

BPT treatment is achieved by the following process:

- Wastewater is collected in an equalization tank. Lime is added to precipitate fluoride and toxic metals.

- The wastewater is transferred to a mixing tank where the pH is raised to 10. Fluorides and metals are precipitated as calcium fluoride and metal hydroxides.

- Solids are settled in a lagoon, dredged, and stored on-site.

To meet BAT regulations, plants will be required to reuse at least 65 percent of the effluent for kiln residue slurrying. This will require an additional treatment step between precipitation and settling.

Pollution control cost estimates have been calculated for three model plant sizes, producing 21,000, 42,000 and 63,000 tons of HF per year. The wastewater flow associated with these plant sizes are 5,200, 10,450 and 15,700 cubic meters per day, respectively. Pollution control costs for the model plants are summarized in Table 6-4.

Hydrogen fluoride manufacturing cost estimates are $710.20, $586.50 and $535.80 per ton for the small, medium and large plants respectively. These cost estimates are based on the estimates presented in Table 6-3 and include the cost of meeting BPT effluent limitations. Table 6-5 summarizes the cost parameters used in the model plant analysis.

The total annualized and investment costs for the hydrogen fluoride subcategory are summarized in Table 6-6. These costs are based on the model plant pollution control costs and current industry production levels. All hydrogen fluoride manufacturers have BPT removal equipment in place. The total additional cost to the subcategory for compliance with BAT removal levels is $377,876.

6.2.2 Model Plant Analysis

This section outlines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

- Price Rise - the calculation of the price increase required to fully recover the increased pollution control costs.

- Profitability Decline - the maximum decline in profitability that would result if no price increase were possible.

- Price Elasticity of Demand - a subjective estimate based on information developed in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.

- The Capital Ratio - the ratio of pollution control capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

6.2.2.1 Price Rise Analysis

The price rise analysis assumes full pass-through of all pollution control costs. Table 6-7 summarizes the price rise required of each model plant for BAT levels of removal. The price increase necessary to pass through the incremental pollution control costs of BAT is less than four-tenths of one percent for all model plants.

6.2.2.2 Profitability Analysis

The profitability analysis examines the decline in the return on investment (ROI) and internal rate of return (IRR) when no price pass-through is possible. For BAT removal levels the smallest model plant incurs a decline in the IRR of one-half of one percentage point, representing an 11.61 percent decline from the base case, and the ROI decreases by less than one-half of one percentage point or decreases by only 6.11 percent of baseline profitability. The two larger model plants have smaller declines in the ROI and IRR. These results are summarized in Table 6-8.

TABLE 6-4: POLLUTION CONTROL COSTS

Chemical: Hydrofluoric Acid

Model Plant Production (tons/year)	BPT/PSES		BAT*	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
21,000	$2,324,721	$1,170,014	$ 68,310	$31,880
42,000	3,923,267	2,175,525	106,260	38,414
63,000	5,922,964	3,233,985	151,800	45,834

*BAT costs represent incremental costs above BPT costs.
Source: Technical Contractor

TABLE 6-5: MANUFACTURING COSTS

Chemical: Hydrofluoric Acid

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs* Per Ton
21,000	$11,320,000	$710.20
42,000	18,390,000	586.50
63,000	24,400,000	535.80

*Includes the cost of meeting BPT effluent limitations.
Note: All costs are in mid-1978 dollars.

TABLE 6-6
SUBCATEGORY COMPLIANCE COSTS

Chemical: Hydrofluoric Acid

	BAT		
Model Plant Production (tons/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)
21,000	77,520	$409,860	$172,094
42,000	87,650	212,520	127,969
63,000	62,250	151,800	77,813
TOTAL	227,420	774,180	377,876

TABLE 6-7

PERCENTAGE PRICE RISE

Chemical: Hydrofluoric Acid

Price: $650/ton

Model Plant Production (tons/year)	BAT
21,000	0.34%
42,000	0.22%
63,000	0.19%

TABLE 6-8

PROFITABILITY CHANGE

Chemical: Hydrofluoric Acid

Level: BAT

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
21,000	5.89%	5.53%	-0.36% (-6.11%)	4.48%	3.96%	-0.52% (-11.61%)
42,000	13.99%	13.84%	-0.15% (-1.07%)	14.01%	13.83%	-0.18% (-1.28%)
63,000	17.17%	17.01%	-0.16% (-0.93%)	17.23%	17.08%	-0.15% (-0.87%)

6.2.2.3 Price Elasticity of Demand

While there are few substitutes for HF which currently threaten any of its major uses, imports represent a constraint on domestic prices. Therefore, the demand for HF is assumed to be moderately price elastic. (See Sections 6.1.1, Demand, and 6.1.3, Competition, for a complete analysis.)

6.2.2.4 Capital Analysis

Raising the capital necessary to install the pollution control equipment is a potential problem for a firm. The capital requirements of the suggested HF pollution control technologies for BAT pollution control are minimal. The required investment in control equipment is approximately 0.6 percent of the plant's total fixed investment. (See Table 6-9). These modest capital requirements should not pose a problem for the subcategory.

6.2.2.5 Closure Analysis

Table 6-10 summarizes the price elasticity of demand, price rise, and profitability decline for hydrogen fluoride model plants and compares these to EPA's closure criteria (see methodology description). For BAT removal levels no plant closures are predicted. For the medium and large size model plants, the calculated price increase is less than one percent, and the decrease in profitability is less than one percentage point and less than ten percent of baseline profitability. For the small model plant size, the decrease in profitability is slightly greater than ten percent of baseline profitability (11.61 percent). However, a complete price pass-through is likely and would result in a price rise of less than 0.4 percent. This price pass-through of pollution control costs should mitigate any profitability declines. Therefore, no plant closures are projected for this subcategory.

6.2.3 Industry Impacts

In this section, the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on hydrogen fluoride manufacturers.

The demand for hydrogen fluoride has decreased substantially since 1974. The EPA ban on fluorocarbon aerosols eliminated one of hydrogen fluoride's major markets. The resulting decline in demand prompted a number of plant closings. Four plants have closed since 1974, reducing industry capacity by 31 percent. If the EPA expands fluorocarbon regulation to include other uses, demand will continue to diminish and further closures can be expected. Even if demand stabilizes, some producers could be threatened by increasingly competitive imports.

6.2.3.1 Price and Profitability Impacts

The price rise required to fully pass through the pollution control costs incurred by going from BPT to the more stringent BAT removal level is no more than 0.40 percent. This is considered inconsequential.

Table 6-8 presents the profitability changes resulting from the firms fully absorbing the costs of BAT pollution control. The changes in the ROI and IRR from this control level are small. For the medium and large size model plants, the reduction is one-half of one percentage point or less, which represents a decrease of less than ten percent of the baseline profitability levels. For the small model plant the maximum profitability decline of 0.52 percentage points represents an 11.61 percent decrease from baseline profitability, exceeding the EPA closure criterion of a ten percent change in baseline profitability. Because demand is only moderately price elastic and the required price rise is minimal (0.34 percent), a complete pass-through of pollution control costs is likely. This price pass-through should mitigate any profitability

TABLE 6-9

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemcial: Hydrofluoric Acid

Level of Removal	Model Plant Production (tons/year)		
	21,000	42,000	63,000
BAT	0.6%	0.6%	0.6%

TABLE 6-10

IMPACT SUMMARY

Chemical: Hydrofluoric Acid

CLOSURE CRITERIA	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater Than 10% of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE (% DECLINE)	CLOSURES
	21,000		0.34%	0.52% (11.61%)	no
BAT	42,000	Medium	0.22%	0.18% (1.28%)	no
	63,000		0.19%	0.15% (0.87%)	no

SOURCE: EEA estimates.

declines. The model plant analysis indicates that the cost of achieving BAT control should not pose a problem for the industry.

6.2.3.2 New Source Standards

New source performance standards (NSPS) and pretreatment standards for new sources (PSNS) for the hydrogen fluoride subcategory will require a different control technology from that discussed above for existing plants. Pollution control for new plants will involve lime and soda ash precipitation, recycle of 65 percent of the effluent, and dry handling of kiln waste in order to reduce the waste load and effluent flow. This treatment system is available to new plants since they have the opportunity to design and install the most efficient control systems. The costs for this system are similar to or slightly less than BPT removal costs. Since all current hydrogen fluoride plants are now incurring the costs of BPT removal, new sources will not be operating at a cost disadvantage. Therefore, new source performance standards will not result in more severe impacts on new producers and are not expected to significantly discourage new hydrogen fluoride plants from entering this subcategory.

7. NICKEL SULFATE

7.1 CHARACTERIZATION

(NOTE: As discussed below in Section 7.2, this industry subcategory incurs no compliance costs. The following characterization data is presented for informational purposes only.)

Nickel sulfate ($NiSO_4$) is a low volume chemical used primarily in metal plating (see Figure 7-1 for sources and uses of nickel sulfate). Total production of nickel sulfate has declined from a high of about 21,000 short tons in 1969 to 7,032 tons in 1977. This represents a 15 percent average annual decrease in demand for nickel sulfate.

Two factors are contributing to the decline in nickel sulfate demand:

- Metal platers, the primary purchasers of nickel sulfate, are recycling nickel sulfate solution in an effort to meet 1973 water pollution control regulations
- Some end markets for plated metal, particularly the automobile industry, are replacing plated parts with plastics and aluminum, because they are lighter.

Recycling efforts and substitution of other materials will cause nickel sulfate production to continue declining for the next few years.

7.1.1 Demand

7.1.1.1 End Markets

Most nickel sulfate (between 80 and 90 percent, according to industry sources) is used in metal plating. The remainder is used in the manufacture of hydrogenation catalysts.

Electroplating

Electroplating is a process whereby objects are coated with a thin layer of one or more metals in order to improve the appearance, durability, or electrical properties of the surface. The process involves placing the object to be plated in a bath containing a metal salt. An electric current is passed through the solution and the object such that the metal from the salt (nickel in the nickel sulfate solution) attaches itself to the surface of the object.

Between 10,000 and 20,000 electroplating installations in the United States use nickel sulfate. Of these, almost 3,000 are independently owned and operated electroplating shops. The remainder are captive operations engaged in the manufacture of products or parts that require plating, such as automobile bumpers.

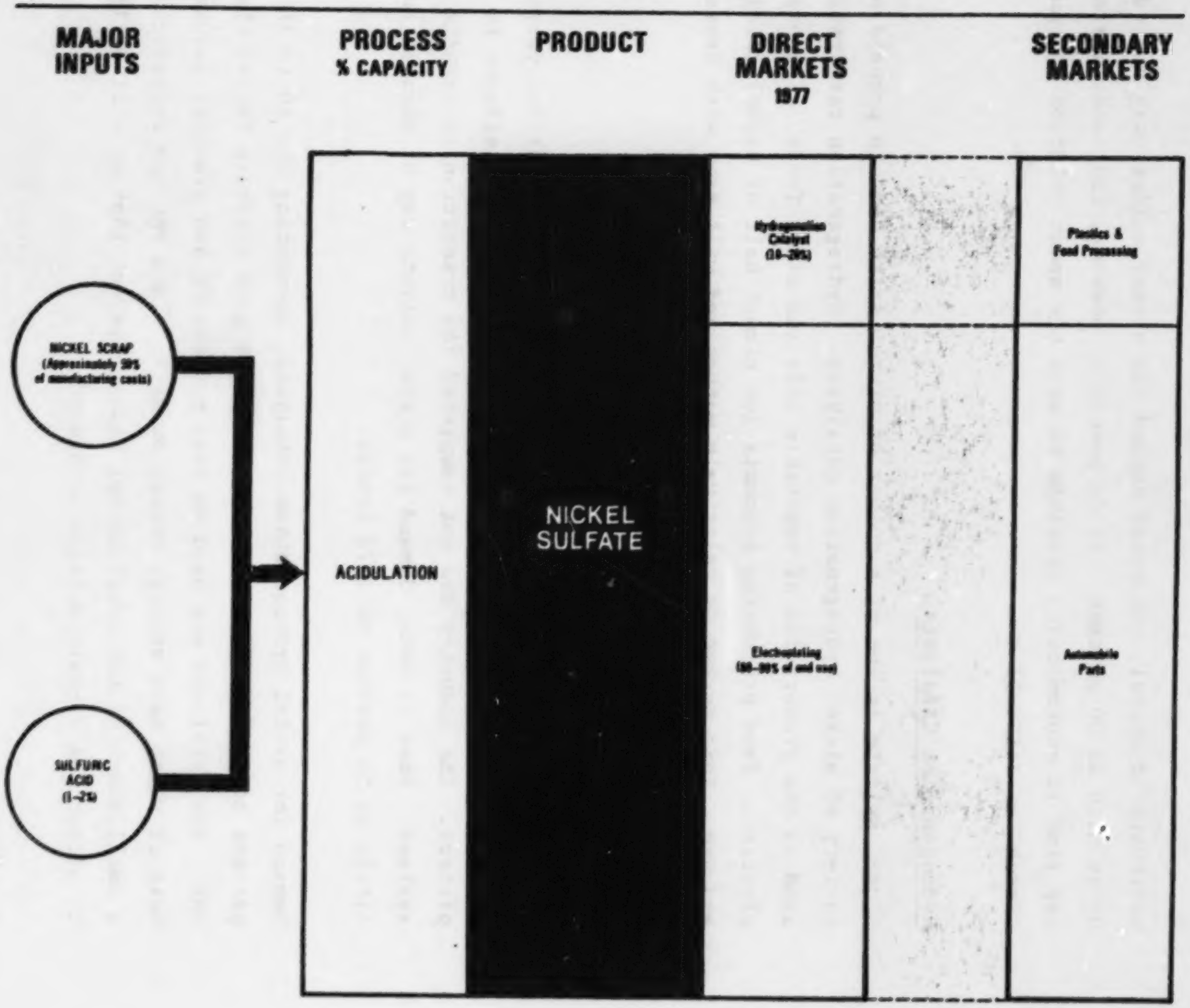
Nickel is used in all decorative plating applications. A relatively thick (0.4 - 1.5 mm) coating of nickel is applied as a base (or over a layer of copper) and is then covered by a thin layer of chromium. The nickel base acts to inhibit corrosion; the chromium resists tarnish. Electroplating industry sources estimate that 40 to 50 percent of nickel plating is used by the automobile industry in the chroming of steel bumpers and decorative trim. Nickel plating is also used in marine hardware, tools and appliances, and electronics..

Plating has many applications and is used by a number of industries. Therefore, demand for plating is dependent on the demand for the plated end products, such as automobiles and appliances. However, production of nickel sulfate has declined due to increased recycling of the chemical.

Because of these recovery efforts, demand for nickel sulfate is expected to decline for the next five to 10 years, although the rate of this decline is uncertain. As platers install closed loop systems to avoid

FIGURE 7-1

NICKEL SULFATE: INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
NICKEL SCRAP (Approximately 50% of manufacturing costs)
SULFURIC ACID (1–2%)
ACIDULATION
NICKEL SULFATE
Hydrogenation Catalyst (10–20%)
Electroplating (80–90% of end use)
Plastics & Food Processing
Automobile Parts

wastewater disposal, the total demand for nickel sulfate may be reduced by as much as 50 percent. It is possible, however, that some platers may find it economically feasible to sell the spent solution and purchase "fresh" nickel sulfate.

Hydrogenation Catalysts

Nickel sulfate is one of a number of nickel salts used to prepare a variety of nickel hydrogenation catalysts. Hydrogenation catalysts are used in the preparation of vegetable oils and other foods, alcohols, and plastics. Food processing accounts for almost half of nickel catalyst end use. This market is relatively mature and will grow with Gross National Product.

7.1.1.2 Demand Summary

Demand for nickel has decreased substantially in the last few years. The decline is primarily due to the increased recycling efforts by metal platers. The industry has not completed its transition to recycle systems. When it does, demand for nickel sulfate may be reduced to as little as 50 percent of 1973 levels.

Demand for nickel hydrogenation catalysts, accounting for 10 to 15 percent of the nickel sulfate market, will grow slightly faster than the GNP. The catalysts are used in food processing and plastics industries, both of which have strong, steady markets. This end use represents such a small share of the total nickel sulfate market that it will do little to offset the overall decline in demand.

7.1.2 Supply

7.1.2.1 Production

Nickel sulfate production was only seven thousand tons in 1977, a very low volume compared to some other inorganic chemicals. (For example,

TABLE 7-1

PRODUCTION OF NICKEL SULFATE

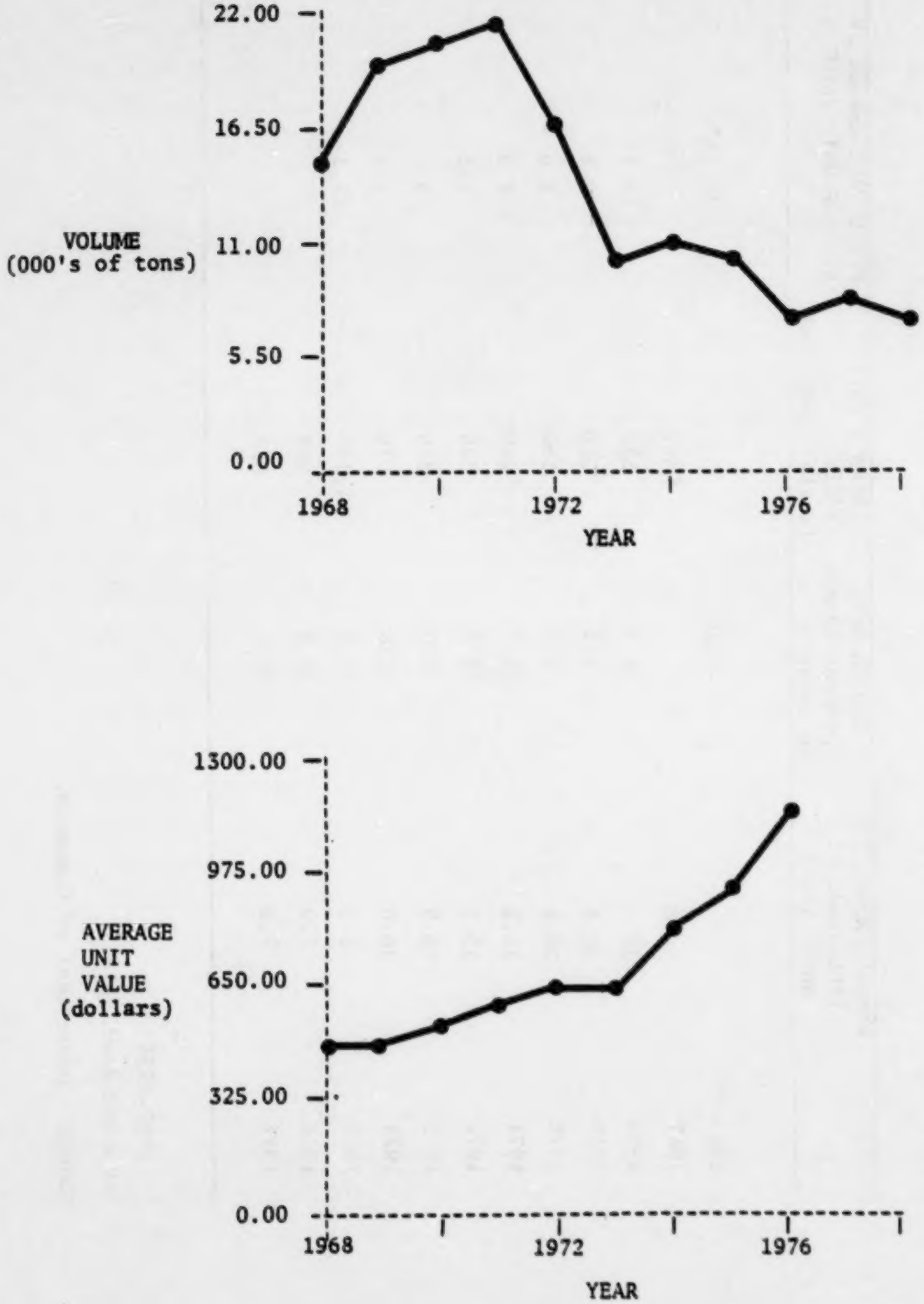
YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (dollars per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1967-77		-7.2%		11.1%*
1967	14.8		$490	
1968	19.6	31.7	510	4.1
1969	20.4	4.3	560	9.8
1970	20.9	2.5	580	3.6
1971	16.8	-19.7	630	8.6
1972	10.3	-38.4	670	6.3
1973	10.9	5.9	830	9.0
1974	10.0	-8.8	910	4.8
1975	6.9	-31.0	1,140	25.3
1976	7.9	15.4	N/A	
1977	7.0	-11.5	N/A	

* 1967-1975

NA = Not Available

SOURCE: Department of Commerce.

GRAPH 7-1
NICKEL SULFATE PRODUCTION AND PRICE



SOURCE: Department of Commerce

production of chlorine, a major inorganic chemical, was 10 million tons in 1977.) As discussed above, nickel sulfate production has declined steadily since 1967 (see Table 7-1 and Graph 7-1). The average rate of production decline since 1967 has been 7.2 percent annually. The slight production rise in 1976 represents a recovery from abnormally low levels brought about by the 1974-75 recession. Nickel sulfate manufacturers expect the decline in production to continue due to falling nickel sulfate demand.

The sharp demand decline should cease within five to 10 years as the metal plating industry completes its transition to nickel recovery systems. By that time, the previously steep production decline will moderate to less than two percent annually.

7.1.2.2 Producers

There are 10 producers of nickel sulfate operating 11 plants (see Table 7-2) The newest producer, Federated Metals Corporation, began nickel sulfate production in October 1978. Four large, multi-industry companies account for most of the production: Harshaw Chemical Company, McGean Chemical Co., Inc., C.P. Chemicals, Inc., and M&T Chemicals. The remaining plants produce only small amounts of nickel sulfate, often as a by-product in copper refining operations. Captive use is believed to be very low. Specific capacity figures are not available, but recent estimates indicate that Harshaw Chemical, a subsidiary of Kewanee Industries, Inc., and C.P. Chemicals each account for about 30 percent of industry production.

7.1.2.3 Process

Nickel sulfate is produced from two types of raw materials: pure nickel or nickel oxide, and impure nickel-containing materials (e.g., spent nickel catalysts, nickel carbonate). In the first case, the metal or oxide is digested in sulfuric acid and filtered. The liquid then is either sold or further processed into a solid. In the second case, the raw materials also are digested in sulfuric acid. The solution is then treated in series with oxidizers, lime, and sulfides to precipitate impurities. The solution is filtered and marketed or further processed into a solid.

The reaction is as follows:

$$Ni + H_2SO_4 \rightarrow NiSO_4 + H_2$$

In addition, some nickel sulfate is produced as a by-product during copper refining operations.

Nickel sulfate manufacturing costs are presented in Table 7-3. Based on an average of three plant sizes, the total cost of manufacturing nickel sulfate was estimated to be approximately $1,660 dollars per short ton (see Table 7-3). The cost of raw materials (primarily nickel) accounts for 50 to 75 percent of the manufacturing costs. Total fixed investment for a nickel sulfate plant having an annual capacity of 6,000 tons is estimated to be five million dollars (mid-1978 dollars).

7.1.3 Competition

Nickel sulfate is sold by the manufacturer directly to consumers (primarily metal platers) in either solid or liquid form. Producers of nickel sulfate compete mainly on the basis of price. One producer, C.P. Chemicals, has been particularly aggressive in pricing. By consistently selling below other producers' list prices, C.P. Chemicals has gained a significant market share in only a few years. Another source of low priced nickel sulfate is the group of copper refiners who produce small quantities of the chemical during copper refining. They often sell their nickel sulfate on the market at very low prices in an attempt to sell the by-product quickly. The intense price competition keeps profits on nickel sulfate sales very low. Producers who sell a number of chemi-

TABLE 7-2

PRODUCERS OF NICKEL SULFATE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
C.P. Chemicals, Inc.	Sewaren, NJ	N/A	30%*		
Federated Metals Corp.	Hammond, IN	N/A			
Harshaw Chemical Co.	Cleveland, OH		30%*		
Harstan Chemical Corp.	Brooklyn, NY				
Kennecott Copper Corp.	Salt Lake City, UT	N/A		Sulfuric Acid	
M&T Chemicals, Inc.	East Chicago, IL Pico Rivera, CA	N/A			
Mallinckrodt, Inc.**	St. Louis, MO	N/A			
McGean Chemical Co., Inc.	Cleveland, OH	N/A	25%*		
PVO International, Inc.	Boonton, NJ	N/A			
Richardson-Merrell, Inc.	Phillipsburg, NJ	N/A			

N/A = Not Available.

* EEA estimates from industry sources.

** Produces high purity nickel sulfate only.

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TABLE 7-3a

ESTIMATED COST OF MANUFACTURING NICKEL SULFATE*
(mid-1978 dollars)

Plant Capacity	1,400 tons/year
Annual Production	990 tons/year (71% capacity utilization)
Fixed Investment	$2.0 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Nickel Metal (scrap)	785 lb	1.35	1059.10
- Sulfuric Acid (66 Bé)	1510 lb	.016	24.20
• Utilities			
- Power	91 kWh	.03	2.70
- Cooling Water	36 kgal	.10	3.60
- Steam	9 klb	3.25	29.50
- Process Water	6 kgal	.75	4.80
Total Variable Costs			$1123.90
SEMI-VARIABLE COSTS			
• Labor			461.90
• Maintenance			80.60
Total Semi-Variable Costs			$ 542.50
FIXED COSTS			
• Plant Overhead			115.50
• Depreciation			201.50
• Taxes & Insurance			30.20
Total Fixed Costs			$ 347.20
TOTAL COST OF MANUFACTURE			$2013.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 7-3b

ESTIMATED COST OF MANUFACTURING NICKEL SULFATE*
(mid-1978 dollars)

Plant Capacity	6,200 tons/year
Annual Production	4,400 tons/year (71% capacity utilization)
Fixed Investment	$5.0 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Nickel Metal (scrap)	785 lb	1.35	1059.10
- Sulfuric Acid (66 Bé)	1510 lb	.016	24.20
• Utilities			
- Power	91 kWh	.03	2.70
- Cooling Water	36 kgal	.10	3.60
- Steam	9 klb	3.25	29.50
- Process Water	6 kgal	.75	4.80
Total Variable Costs			$1123.90
SEMI-VARIABLE COSTS			
• Labor			183.10
• Maintenance			45.40
Total Semi-Variable Costs			$ 228.50
FIXED COSTS			
• Plant Overhead			45.80
• Depreciation			113.40
• Taxes & Insurance			17.10
Total Fixed Costs			$ 176.30
TOTAL COST OF MANUFACTURE			$1528.70

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 7-3c

ESTIMATED COST OF MANUFACTURING NICKEL SULFATE*

(mid-1978 dollars)

Plant Capacity	10,800 tons/year
Annual Production	7,700 tons/year (71% capacity utilization)
Fixed Investment	$7.3 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Nickel Metal (scrap)	785 lb	1.35	1059.10
- Sulfuric Acid (66 Be´)	1510 lb	.016	24.20
• Utilities			
- Power	91 kWh	.03	2.70
- Cooling Water	36 kgal	.10	3.60
- Steam	9 klb	3.25	29.50
- Process Water	6 kgal	.75	4.80
Total Variable Costs			$1123.90
SEMI-VARIABLE COSTS			
• Labor			127.30
• Maintenance			37.80
Total Semi-Variable Costs			$ 165.10
FIXED COSTS			
• Plant Overhead			31.80
• Depreciation			94.60
• Taxes & Insurance			14.20
Total Fixed Costs			$ 140.60
TOTAL COST OF MANUFACTURE			$1429.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

cals to the plating industry continue to manufacture and sell nickel sulfate in order to complete a chemical product line.

There are no substitutes for nickel sulfate in its primary end use, metal plating. However, automobile manufacturers have begun switching to materials such as plastic and aluminum (which do not require protective metal plating) in an effort to reduce automobile weight. These alternatives to plated metals have not been well received -- consumers seem to prefer chromed bumpers to those made of plastic or brushed aluminum. Manufacturers of plastic and aluminum parts are, therefore, engaged in finding ways of improving the appearance of their product, such as applying a metal finish to the plastic. Nevertheless, lightweight plastic and aluminum are certain to become more widely used by the automobile industry in the interest of lighter cars and gasoline mileage improvements.

7.1.4 Economic Outloook

7.1.4.1 Revenue

Total revenue is the product of quantity sold and average unit price. Although these two variables are discussed separately, they are interrelated.

7.1.4.1.1 Quantity

Nickel sulfate is at the end of its product life cycle. Volume of sales, which has been declining at about six percent per year for the last 10 years, will continue to decline due to the following:

- Manufacturers will continue to substitute lightweight plastics and aluminum for heavier plated metals in many applications
- The metal plating industry will require less nickel sulfate due to recycling systems which allow spent nickel sulfate solution to be reused

- The development of more efficient electroplating methods will affect the market for nickel sulfate and other electroplating chemicals. A system recently tested by Bell Telephone Laboratories reduces chemical wastes by 90 percent and is less polluting (Chemical Marketing Reporter, April 22, 1978).

These factors will continue to reduce nickel sulfate's sales volume by about six percent per year for the next three to five years. Producers expect the decline to become more gradual (about zero to two percent per year) in the mid-1980's.

7.1.4.1.2 Price

The single most important factor in nickel sulfate's price is the price of nickel, discussed in the following section. Price also is influenced by competitive market factors, such as aggressive pricing policies on the part of nickel sulfate manufacturers seeking an increased market share for their line of electroplating chemicals.

7.1.4.2 Manufacturing Costs

The cost of manufacturing nickel sulfate is dependent on the price of nickel. Most of the nickel used by nickel sulfate manufacturers is imported from Canada since very little nickel ore is mined domestically. However, some nickel is supplied by a domestic company (Amax Nickel, Port Nickel, LA) that refines imported nickel ore. At current prices (about $2.00 per pound), the cost of nickel represents at least half of the total manufacturing costs. Almost all of the remaining cost is shared equally by labor, maintenance, and plant overhead costs.

7.1.4.3 Profit Margins

Profitability in the nickel sulfate industry has always been marginal. Profitability will erode even further due to:

- Declining sales: the primary consumers of nickel sulfate, metal platers, are reducing their consumption through nickel sulfate recycle systems.

- Competitive pricing: manufacturers will continue to price competitively in an effort to win a larger market share for their complete line of electroplating chemicals.
- Rising costs: nickel prices are expected to rise at a 7 to 10 percent annual rate in the long run.

Despite the bleak profitability outlook, manufacturers will continue to produce and sell nickel sulfate in order to offer customers a complete line of electroplating chemicals.

7.1.5 Characterization Summary

Production of nickel sulfate, used primarily in electroplating, has declined to about one-third of 1970 levels. Demand has fallen due to efforts by the electroplating industry to recycle nickel sulfate in order to meet water pollution standards. Consumers of plated metals, especially the automobile industry, are turning to plastic and aluminum substitutes because they are lightweight. The development of a more efficient plating process is likely to further erode nickel sulfate demand.

In addition to its use in electroplating, nickel sulfate is used in the manufacture of hydrogenation catalysts. These are used by the food processing and plastics industries, which are growing steadily. However, only 5 to 10 percent of nickel sulfate production is used in hydrogenation catalyst manufacture. Therefore, growth in this market will not affect the overall decline in nickel sulfate production.

7.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the nickel sulfate subcategory to comply with BAT and PSES effluent control standards. EPA has determined that no plants in this subcategory will incur compliance costs under this rulemaking:

- All five direct dischargers already have BPT in place, and BAT has been set equal to BPT for this subcategory.

- Pretreatment standards for indirect dischargers were promulgated previously. The current rulemaking revises the limitations to equal BAT, but does not change the technology basis or the compliance costs. Therefore, while two of the six indirect dischargers may not have treatment in place, the compliance costs they will have to incur are attributable to an earlier PSES rulemaking (40 CFR 415.374). There are no additional compliance costs associated with the current regulation.

Accordingly, these regulations will have no economic impact on the subcategory.

7.2.1 Pollution Control Technology and Costs

As noted above, no plants will incur control costs under this rulemaking. The following detail on control technology and costs is provided for informational purposes only.

Capital and operating costs were developed by the technical contractor for the pollution control technologies designed to meet BAT/PSES removal levels. Both BAT and PSES are equivalent to BPT for this subcategory.

The major pollutants in nickel sulfate production are solid waste metals. To achieve BPT/PSES, the following procedure is used:

- Caustic soda is added to precipitate metals.
- The overflow from the settling tank is filtered and discharged after pH adjustment.
- Solids, filtered from the settling tank, are landfilled.

Pollution control cost estimates were developed for three model plant sizes, with production rates of 990 tons per year (TPY), 4,400 TPY, and 7,700 TPY. Table 7-4 summarizes pollution control costs for the model plants.

TABLE 7-4: POLLUTION CONTROL COSTS

Chemical: Nickel Sulfate

Model Plant Production (tons/year)	BPT/PSES		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
990	$ 86,512	$ 24,457	For this subcategory, BAT is the same as BPT. There are no incremental costs over BPT for compliance with BAT regulations.	
4,400	141,911	32,308		
7,700	199,581	40,396		

Source: Technical Contractor

8. SODIUM BISULFITE

8.1 CHARACTERIZATION

Sodium bisulfite ($NaHSO_3$), also called sodium hydrogen sulfite and sodium acid sulfite, is a chemical widely used as a reducing agent. A reducing agent has the ability to change the chemical properties of another chemical by adding one or more electrons. For example, hexavalent chromium, the highly toxic form of chromium, can be reduced by sodium bisulfite to less toxic trivalent chromium. Treatment of chromium-containing wastewater is one of sodium bisulfite's major end uses. The other uses for sodium bisulfite, all of which utilize its reducing ability, include photographic processing, food processing, tanning, and textile manufacturing (see Figure 8-1).

8.1.1 Demand

While Bureau of Census data are unavailable, the total annual market for sodium bisulfite is estimated at just under 100,000 tons. This market should grow with Gross National Product, since sodium bisulfite is a mature product and its end markets are fairly diverse.

In order to depict the total demand for sodium bisulfite, the conditions in its individual end markets are summarized below.

8.1.1.1 End Markets

Photographic Processing -- Approximately half of sodium bisulfite production is used in photographic processing. Manufacturers sell to large photo-processing concerns (e.g., Kodak) as well as photography supply houses that repackage the chemical for sale to small users. This is a very secure market for sodium bisulfite since there are no other proces-

sing agents which are as effective and inexpensive. Demand in this market is expected to grow with Gross National Product.

Food Processing and Preservatives -- Approximately 30 percent of sodium bisulfite production is used in food processing and as a food preservative. This market is very secure because sodium bisulfite inhibits the growth of specific yeasts and is less expensive than alternative preservatives. Processes using sodium bisulfite include canning, winemaking, sugar syrup processing, and vanillin (artificial vanilla) manufacture. Because this end-use is closely tied to the food industry, growth in the end market is expected to grow with population.

Water Treatment -- Sodium bisulfite is used in effluent treatment of toxic and chrome wastes. Because it is easy to handle in powder form, sodium bisulfite is widely used to treat smaller quantities of wastewater. When large quantities are involved, sulfur dioxide is preferred due to its lower cost. However, handling difficulties associated with sulfur dioxide give sodium bisulfite a competitive edge in some uses. Growth in this end-use market may grow slightly ahead of GNP, according to industry sources.

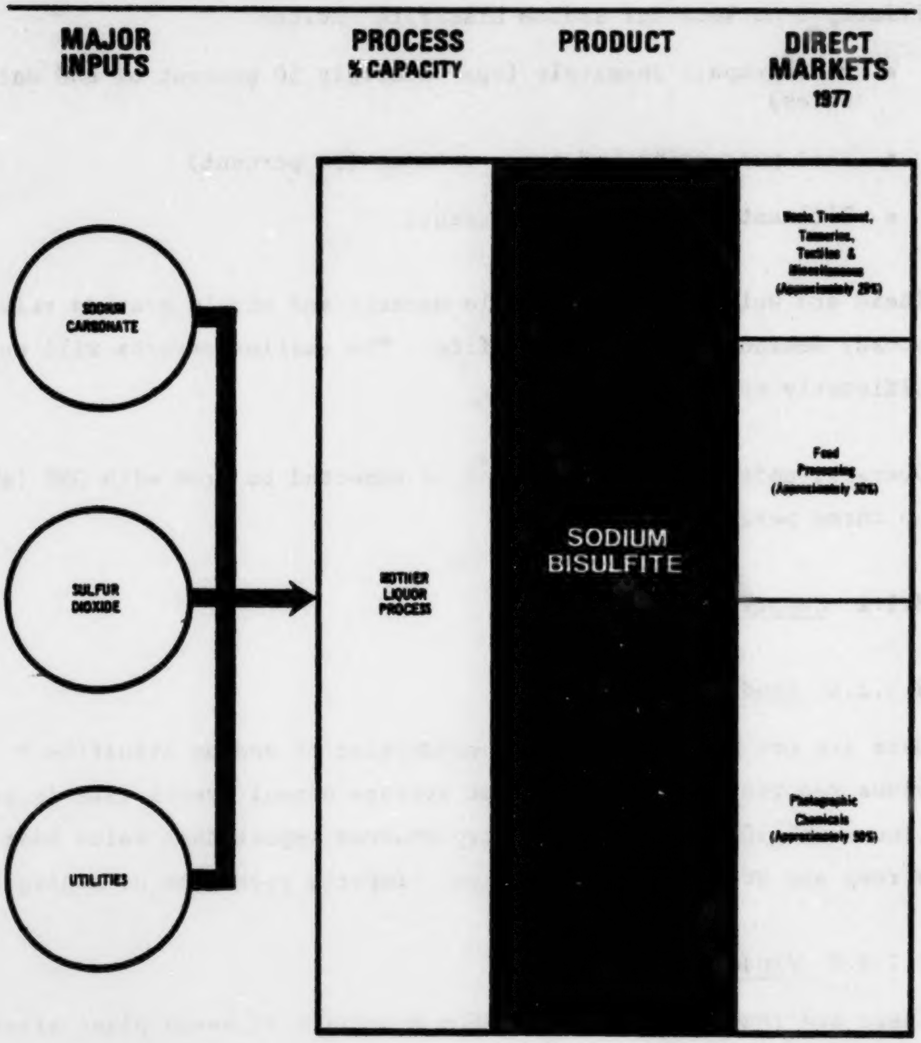
Other Markets

Sodium bisulfite is used in a number of other applications:

- Textile manufacture -- Bisulfite is used as antichlor after bleaching and dying. Demand fluctuates with textile imports and fashion changes, which makes it difficult to forecast demand in this market.
- Leather tanning -- This market is expected to grow at a moderate pace (about 2 to 5 percent annually) due to a strong export demand for leather.
- Manufacture of L-Dopa (a drug used to treat Parkinson's Disease) -- This market is not likely to experience any growth and should eventually decline.

FIGURE 8-1

SODIUM BISULFITE:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS 1977
SODIUM CARBONATE
SULFUR DIOXIDE
UTILITIES
MOTHER LIQUOR PROCESS
SODIUM BISULFITE
Waste Treatment, Tanneries, Textiles & Miscellaneous (Approximately 20%)
Food Processing (Approximately 30%)
Photographic Chemicals (Approximately 50%)

- Preparation of chemicals such as aldehydes and surfactants (wetting agents) -- This market should grow with Gross National Product.

8.1.1.2 Demand Summary

Principal markets for sodium bisulfite include:

- Photographic chemicals (approximately 50 percent of end market sales)
- Food processing and preservatives (30 percent)
- Effluent treatment (10 percent)

These are well developed, stable markets and should provide relatively steady demand for sodium bisulfite. The smaller markets will not significantly affect total demand.

Overall, sodium bisulfite demand is expected to grow with GNP (about two to three percent annually).

8.1.2 Supply

8.1.2.1 Production

Data are not available for the production of sodium bisulfite.* Previous reports show a 5.5 percent average annual growth rate in production from 1968 to 1974. Industry sources report that sales have been strong and steady since that time. Imports appear to be negligible.

8.1.2.2 Producers

There are four producers of sodium bisulfite at seven plant sites in the United States. Exact capacity figures for some plants are not available (see Table 8-1).

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* Very little information has been available on the sodium bisulfite industry due to two factors: (1) the Department of Commerce does not collect data on this chemical; and (2) individual firms are reluctant to disclose information.

TABLE 8-1

PRODUCERS OF SODIUM BISULFITE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
Allied Chemical	Al Sequndo, CA North Claymont, DE	40,000	37	Soda Ash Sulfur Dioxide	
DuPont	Linden, NJ	20,000	19	Sulfur Dioxide	
Virginia Chemicals	Mobile, AL Chester, SC Portsmouth, VA	40,000	37	Sulfur Dioxide	
Olympic Chemicals	Tacoma, WA	8,000	7		
TOTAL		108,000	100		

EEA estimates from industry sources.

Allied Chemical and Virginia Chemicals are the major producers of sodium bisulfite, probably accounting for most of the production capacity of the industry. The two manufacturers produce the chemical in both liquid and powdered form. DuPont markets sodium bisulfite in a 38 percent solution. Olympia Chemicals also manufactures the liquid form, the bulk of which is sold to a nearby Monsanto plant.

Allied is integrated backwards to two major raw materials: soda ash and sulfur dioxide. Virginia Chemicals and DuPont produce only sulfur dioxide. Captive use is very low. Virginia Chemicals expanded its capacity sometime between 1973 and 1977. Since that time, no new expansions have been planned by either company.

8.1.2.3 Process

Sodium bisulfite is produced by a variety of methods. The bulk of the commercial product is sodium metabisulfite ($Na_2S_2O_5$, a dehydrated derivative of two $NaHSO_3$ molecules).

Dry Process

Moist soda ash is treated with a gas containing 49 percent sulfur dioxide and less than four percent oxygen. The product, sodium metasulfite, is discharged from the reactor and crushed.

Liquid Process

A saturated solution of sodium bisulfite is prepared by combining sodium hydroxide and sulfur dioxide. Savings are realized in fuel, bagging, etc. Extra costs, however, are incurred in transportation so liquid plants must be located close to their markets (usually within 300 miles).

"Mother Liquors" Process

Sodium bisulfite is produced by passing seven to eight percent sulfur dioxide through a suspension of soda ash in mother liquors saturated with sodium bisulfite. The product is obtained from the solution by centrifuging.

Material requirements and estimated costs of manufacturing by the mother liquor process are presented in Table 8-2. Raw material costs account for between one-third and one-half of total costs. Capital costs vary from 127 dollars per ton of capacity to 247 dollars per ton of capacity. This is a relatively low per-ton capital investment (capital investment in chlorine manufacture is about $280 per ton; in titanium dioxide, $900 per ton).

8.1.3 Competition

The two largest sodium bisulfite manufacturers, Allied Chemicals and Virginia Chemicals, account for 90 percent of sales in the industry. As an effective duopoly (by definition, an industry with only two suppliers) they are likely to set a price and market share which maximizes profits for both of them. Repeated price cutting in an effort to invade the other's market is likely to lead to reduced profits for both. (The small producers follow the price lead of the major producers.) This appears to explain the pricing behavior of sodium bisulfite producers. Prices have always been strong and producers have typically not offered discounts on list prices. High industry capacity utilization is also typical of such an industry.

Sodium bisulfite is sold as a liquid (36, 38, or 42 percent solution) or powder (100 lb bags). The liquid is slightly less expensive since drying and bagging costs are not incurred. However, added transportation costs are such that buyers of liquid are usually located close to the plant. Conversely, powdered sodium bisulfite (accounting for the bulk of sodium bisulfite sales) can be easily and economically shipped over long distances (although care must be taken to guard against moisture).

As discussed in Section 8.1.1, there are no substitutes for sodium bisulfite threatening its markets. Industry sources report that this situation is due to the convenience of the powdered material. It can be handled easily and diluted to the desired concentration by the buyer.

TABLE 8-2a

ESTIMATED COST OF MANUFACTURING SODIUM BISULFITE - MOTHER LIQUOR PROCESS*
(mid-1978 dollars)

Plant Capacity	8,500 tons/year
Annual Production	5,000 tons/year (62% capacity utilization)
Fixed Investment	$2.1 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Soda Ash	1129.22 lb	0.034	38.40
- Sulfur Dioxide	1355.97 lb	0.074	100.30
• Utilities			
- Electric Power	101.58 kWh	0.03	3.10
- Steam	1.27 mlb	3.25	4.10
- Cooling Water	3.72 mgal	0.10	.40
Total Variable Costs			$146.30
SEMI-VARIABLE COSTS			
• Labor			55.30
• Maintenance			16.00
Total Semi-Variable Costs			$ 71.30
FIXED COSTS			
• Plant Overhead			13.80
• Depreciation			39.90
• Taxes & Insurance			6.40
Total Fixed Costs			$ 60.10
TOTAL COST OF MANUFACTURE			$277.70

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 8-2b

ESTIMATED COST OF MANUFACTURING SODIUM BISULFITE - MOTHER LIQUOR PROCESS*

(mid-1978 dollars)

Plant Capacity	30,000 tons/year
Annual Production	18,500 tons/year (62% capacity utilization)
Fixed Investment	$4.7 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Soda Ash	1129.22 lb	0.034	38.40
- Sulfur Dioxide	1355.97 lb	0.074	100.30
• Utilities			
- Electric Power	101.58 kWh	0.03	3.10
- Steam	1.27 mlb	3.25	4.10
- Cooling Water	3.72 mgal	0.10	.40
Total Variable Costs			$146.30
SEMI-VARIABLE COSTS			
• Labor			20.50
• Maintenance			10.10
Total Semi-Variable Costs			$ 30.60
FIXED COSTS			
• Plant Overhead			5.10
• Depreciation			25.20
• Taxes & Insurance			3.80
Total Fixed Costs			$ 34.10
TOTAL COST OF MANUFACTURE			$211.00

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 8-2c

ESTIMATED COST OF MANUFACTURING SODIUM BISULFITE - MOTHER LIQUOR PROCESS*
(mid-1978 dollars)

Plant Capacity	56,500 tons/year
Annual Production	35,000 tons/year (62% capacity utilization)
Fixed Investment	$7.2 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Soda Ash	1129.22 lb	0.034	38.40
- Sulfur Dioxide	1355.97 lb	0.074	100.30
• Utilities			
- Electric Power	101.58 kWh	0.03	3.10
- Steam	1.27 mlb	3.25	4.10
- Cooling Water	3.72 mgal	0.10	.40
Total Variable Costs			$146.30
SEMI-VARIABLE COSTS			
• Labor			16.10
• Maintenance			8.20
Total Semi-Variable Costs			$ 24.30
FIXED COSTS			
• Plant Overhead			4.00
• Depreciation			20.50
• Taxes & Insurance			3.10
Total Fixed Costs			$ 27.60
TOTAL COST OF MANUFACTURE			$198.20

SOURCE: Contractor and EEA estimates

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*See Appendix C

Foreign trade in sodium bisulfite is reportedly negligible, although data are unavailable. A small volume of the chemical is imported from Great Britain, and there have been exports to Canada. At least one company has indicated that it plans to pursue European markets in the future.

8.1.4 Economic Outlook

8.1.4.1 Revenue

Total revenue is the product of total sales volume and average unit price. Although these two variables are discussed separately below, they are interrelated.

8.1.4.1.1 Quantity

Sodium bisulfite is a mature product with no competitive substitutes to threaten its markets. Overall growth in these markets will follow growth in the Gross National Product (about two to three percent annually).

8.1.4.1.2 Price

Prices vary according to the quantity and form of the product. Current (summer 1981) prices (per 100 pound bag) are $22.50 on the East coast and $24.50 on the West coast. Historically, prices have risen at an average rate of about 11 percent per year (1969-1979). (See Table 8-3 and Graph 8-1). Future price increases are anticipated as manufacturers continue to successfully pass through manufacturing cost increases (see below).

8.1.4.2 Manufacturing Costs

The two main raw materials in the manufacture of sodium bisulfite are soda ash and sulfur dioxide, which together make up 35 to 50 percent of total manufacturing costs. The per ton price of soda ash has jumped

TABLE 8-3

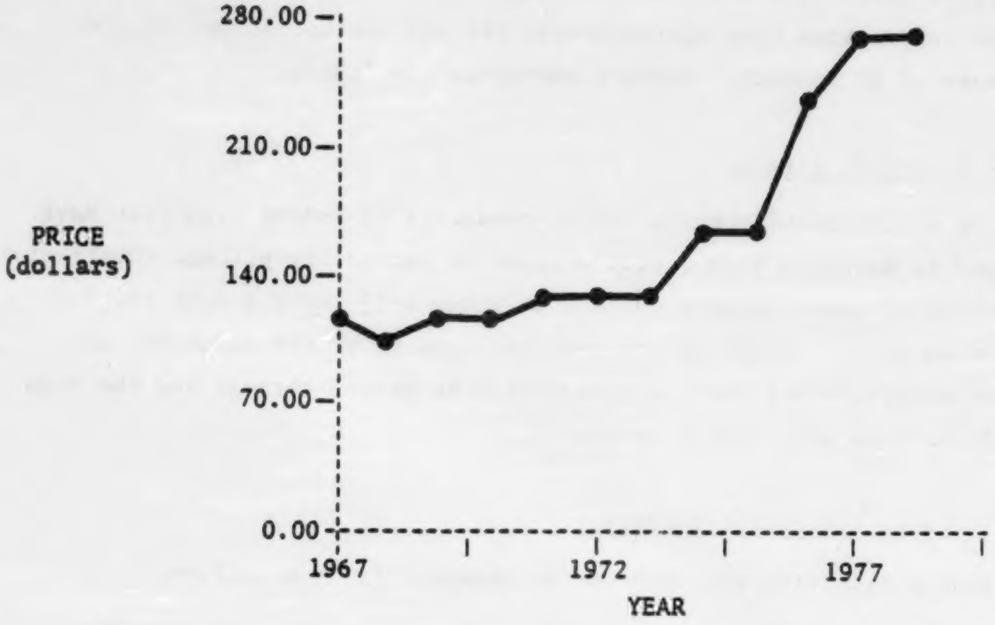
SODIUM BISULFITE LIST PRICES

Year	List Price ($/ton)
1967	$114
1968	110
1969	117
1970	117
1971	127
1972	132
1973	132
1974	162
1975	162
1976	232
1977	267
1978	267

SOURCE: Chemical Marketing Reporter.

GRAPH 8-1

SODIUM BISULFITE PRICE



SOURCE: Department of Commerce

from $55 to $66 in the space of one year. This is due to a tight supply situation caused by several plants shutting down and a delay in the planned construction of new capacity. While the new capacity should ease the tight supply, industry sources expect future price increases.

Sulfur (used to make sulfur dioxide) is also in short supply and the worldwide supply situation is expected to worsen (Chemical Marketing Reporter, April 9, 1979). Between August 1980 and August 1981, crude sulfur prices rose from approximately $47 per ton to $89 per ton, an increase of 89 percent. Further increases are likely.

8.1.4.3 Profit Margins

Despite rising manufacturing costs, producers of sodium bisulfite have managed to maintain high profit margins by increasing prices. Contractor estimates of manufacturing costs (see Table 8-2) imply a high pre-tax margin on sales. Based on the past performance of the industry, all future manufacturing cost increases will be passed through and the high profit margins will remain intact.

8.1.5 Characterization Summary

The sodium bisulfite industry can be characterized as follows:

- Sodium bisulfite is a very efficient, convenient, and economical reducing agent which is used in photographic chemicals, food processing and food preservatives, and wastewater treatment.
- It is manufactured by four firms, two of which (Allied Chemicals and Virginia Chemicals) dominate industry production.
- Total demand for the chemical is estimated by industry sources at just under 100,000 tons per year.
- Because sodium bisulfite is a mature product, demand is expected to grow with Gross National Product (two to three percent annually).

- Profit margins are high and should remain so as manufacturers have been able to pass through increased costs in the form of higher prices.

8.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the sodium bisulfite subcategory to comply with BAT and PSES effluent control standards. The technical contractor has designed and estimated the cost of the effluent control technology required to achieve these standards. The cost of the technology is used to make an assessment of the economic impacts that PSES and BAT control levels will have on the subcategory.

A survey by the technical contractor revealed that six sodium bisulfite manufacturers are direct dischargers and have BPT treatment technology in place. For this subcategory, BAT is the same as BPT. Therefore, these six plants will incur no incremental costs over BPT for compliance with BAT regulations.

The technical contractor's survey also showed that there is one indirect discharger in the sodium bisulfite industry currently not pretreating wastewater. Therefore, the pollution control costs estimated by the technical contractor corresponding to BPT removal are applied to the model plants to assess the impacts of pretreatment costs on this one indirect discharger. Pretreatment costs are equivalent to BPT costs.

8.2.1 Pollution Control Technology and Costs

Capital and operating costs have been developed by the technical contractor for pollution control equipment designed to meet BPT removal.

The major pollutant in the process waste stream is sodium bisulfite product which results in high chemical oxygen demand (COD). To achieve BPT removal, the following procedure is used:

- Caustic soda is added to wastewater to adjust the pH and precipitate toxic metals.
- The effluent is then aerated to reduce COD

Pollution control cost estimates were developed for three model plant sizes with average production rates of 5,000, 18,500 and 35,000 tons per year. Pollution control costs for the model plants are summarized in Table 8-4. Subsequent to the development of these estimates, EPA has determined that the control system is oversized. Therefore, the estimated capital and operating costs for the control technology are overstated.

The costs of manufacturing sodium bisulfite used in the impact analysis were estimated by an economic subcontractor to be \$277.70, \$211.00, and \$198.20 per ton for the small, medium and large plants, respectively. These estimates do not include the cost of pollution control. Table 8-5 summarizes the model plant manufacturing costs used in the analysis.

The total annualized control costs for the sodium bisulfite subcategory are summarized in Table 8-6. These costs are based on the model plant pollution control costs and current industry production levels. All direct dischargers have BPT removal technology in place. For this subcategory, BAT is the same as BPT. Since all direct dischargers have BPT in place and operating, there are no incremental costs over BPT required for compliance with BAT regulations. Therefore, the only additional removal costs will be incurred by the one indirect discharger. PSES costs for this plant are estimated at \$92,337 annually.

8.2.2 Model Plant Analysis

This section outlines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

TABLE 8-4: POLLUTION CONTROL COSTS

Chemical: Sodium Bisulfite

Model Plant Production (tons/year)	BPT/PSES		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
5,000	$144,174	$ 94,443	For this subcategory, BAT and PSES are the same as BPT. There are no incremental costs over BPT for compliance with BAT regulations.	
18,500	215,520	111,418		
35,000	341,478	137,592		

Note: Costs are overstated; see Section 8.2.1

Source: Technical Contractor

TABLE 8-5: MANUFACTURING COSTS

Chemical: Sodium Bisulfite

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs Per Ton
5,000	$2,100,000	$277.70
18,500	4,700,000	211.00
35,000	7,200,000	198.20

Note: All costs are in mid-1978 dollars.

TABLE 8-6

SUBCATEGORY COMPLIANCE COSTS

Chemical: Sodium Bisulfite

		PSES		BAT
Model Plant Production (tons/year)	Estimated Annual Production by Affected Plants (tons)	Investment Costs	Annualized Costs ($/year)	
5,000	3,857	$144,174	$92,337	For this subcategory, BAT and PSES are the same as BPT. Since BPT is in place and operating for all direct dischargers, there are no incremental costs over BPT required for compliance with BAT regulations.
18,500	0	NA	NA	
35,000	0	NA	NA	
TOTAL	3,857	144,174	92,337	

NA: Not applicable-no plants incurring costs

Note: Costs are overstated. See Section 8.2.1

- **Price Rise** - the calculation of the price increase required to fully recover the increased pollution control costs.
- **Profitability Decline** - the maximum decline in profitability that would result if no price increase were possible.
- **Price Elasticity of Demand** - a subjective estimate based on information developed in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.
- **The Capital Ratio** - the ratio of pollution control capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

As noted in Section 8.2.1, the control costs, and thus the estimated impacts, are overstated.

8.2.2.1 Price Rise Analysis

The price rise analysis assumes full pass-through of all pollution control costs. Table 8-7 summarizes the price rise required of each model plant. The model plant price increases required to fully recover the costs of PSES technology range from 2.27 to 8.97 percent.

8.2.2.2 Profitability Analysis

The profitability analysis assumes no price pass-through and calculates the resulting decline in the return on investment (ROI) and the internal rate of return (IRR).

Model plant profitability declines range from 2.1 to 5.41 percentage points, depending on model size (based on ROI). Application of BPT/PSES removal costs reduced the ROI by 5.41 percentage points in the small

TABLE 8-7

PERCENTAGE PRICE RISE

Chemical: Sodium Bisulfite

Price: $267/ton

Model Plant Production (tons/year)	PSES	BAT
5,000	8.97%	For this subcategory, BAT and PSES are the same as BPT. All direct dischargers have BPT in place and operating. There will be no incremental costs have BPT required for compliance with BAT regulations.
18,500	3.18	
35,000	2.27	

model size, representing a decrease in profitability of 64.02 percent, and by approximately 1.44 to 1.62 percentage points, or a profitability decrease of 4.99 to 6.88 percent, in the two larger plants (see Table 8-8).

8.2.2.3 Price Elasticity of Demand

While sodium bisulfite is not a critical input to any process, its major market, photographic processing chemicals, is very secure because no substitutes exist which are as convenient and inexpensive. The same applies to demand in its other major end-use, food processing. This implies relatively inelastic demand for sodium bisulfite in the relevant price range. (See Sections 8.1.1, Demand, and 8.1.3, Competition, for a complete analysis.)

8.2.2.4 Capital Analysis

The investment in BPT/PSES removal equipment required for pretreatment represents roughly five to seven percent of total fixed investment in place (see Table 8-9). These capital requirements can be met without difficulty.

8.2.2.5 Closure Analysis

Table 8-10 summarizes the price elasticity of demand, price rise, and profitability decline for sodium bisulfite model plants and compares these to EPA's closure criteria (see methodology description).

The indirect discharger currently not in compliance with PSES limitations corresponds to the smallest model size. The price increase required to pass through pretreatment costs is greater than one percent for this plant. Further, the profitability decline exceeds one percentage point, and this decline represents 64 percent of the model plant baseline profitability level. Although price elasticity of demand is low, further analysis is required to determine the probability of plant closure for the one indirect discharger. This analysis is presented in the following section.

TABLE 8-8

PROFITABILITY CHANGE

Chemical: Sodium Bisulfite

Level: PSES

Model Plant Production (tons/year)	Return on Investment			Internal Rate of Return		
	Base Case	With Control Equipment	Percentage Point Change (Percent Change)	Base Case	With Control Equipment	Percentage Point Change (Percent Change)
5,000	8.45%	3.04%	-5.41% (-64.02%)	7.59%	*	*
18,500	24.43	22.36	-2.07 (-8.47%)	23.53	21.91	-1.62 (-6.88%)
35,000	31.35	29.21	-2.14 (-6.83%)	28.84	27.40	-1.44 (-4.99%)

*Negative profitability.

TABLE 8-9

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Sodium Bisulfite

	Model Plant Production (tons/year)		
Level of Removal	5,000	18,500	35,000
PSES	6.9%	4.6%	4.7%
BAT	For this subcategory, BAT and PSES are the same as BPT. All direct dischargers have BPT in place and operating. There will be no incremental costs above BPT required for compliance with BAT regulations.		

TABLE 8-10

IMPACT SUMMARY

Chemical: Sodium Bisulfite

CLOSURE CRITERIA	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater than 10% of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE (% DECLINE)	CLOSURES
PSES	5,000		8.97%	5.41%* (64.02%)	no
	18,000	Low	3.18	1.62 (6.88%)	no
	35,000		2.27	1.44 (4.99%)	no

*Based on ROI.

SOURCE: EEA estimates.

8.2.3 Industry Impacts

In this section, the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on sodium bisulfite manufacturers.

Sodium bisulfite is a mature product and its markets are expected to grow with real GNP. While it is not a critical input to any process, its two major markets (photographic processing chemicals and food processing) are very secure because no substitutes exist which are as convenient and inexpensive. Therefore, reasonable price increases could be sustained without an appreciable decline in the quantity demanded.

8.2.3.1 Price and Profitability Impacts

The model plant analysis indicates significant price and profitability impacts for the one indirect discharger in the subcategory. The price rise required for the indirect discharger to fully recover pretreatment costs is about nine percent, a price rise that will not be required by the rest of the subcategory which is already meeting effluent limitations. However, three factors should mitigate the impacts on this plant:

- The indirect discharger should currently be operating with a slight cost advantage since the other plants in the industry have been required to operate pollution control equipment under the promulgated BPT regulations. Since the indirect discharger will need to incur the same costs (plus capital cost inflation), the plant's cost and profit levels will again be in line with the industry-wide levels.

- If the plant does require a price increase to remain competitive, price pass-through is likely. Demand for sodium bisulfite is relatively price inelastic; further, the plant enjoys a regional market advantage since it is one of two bisulfite producers on the West coast. The other West coast producer is very small, and it is unlikely to expand its bisulfite production sufficiently to penetrate the indirect discharger's existing markets.

- The plant is insulated from competition from East Coast producers because of transportation costs. The plant's ability to recover its costs through a price increase will depend on the magnitude of the delivery costs required to ship bisulfite from East Coast producers to West Coast markets relative to the pollution control costs to be incurred by the plant. Based on current price levels, the required price increase (8.97 percent) would raise the affected plant's price from $490/ton to $534/ton. Transportation costs to the West Coast (via rail) would raise the East Coast price of $450/ton to $615/ton. Given this delivered selling price comparison, it appears that the plant would be able to pass through most if not all of its pollution control costs.

These factors suggest that pretreatment standards will not cause severe problems for the indirect discharger.

8.2.3.2 Other Impacts and Conclusion

The price and profitability impacts will not cause severe problems for sodium bisulfite producers. Resulting impacts in areas such as inflation, plant closures, employment, and community disruption, are similarly inconsequential. Sodium bisulfite is neither imported nor exported, so there will be no impact on the balance of payments.

9. SODIUM DICHROMATE

9.1 CHARACTERIZATION

(NOTE: As discussed below in Section 9.2, this industry subcategory incurs no compliance costs. The following characterization data is presented for informational purposes only.)

Sodium dichromate (or sodium bichromate) ($Na_2Cr_2O_7$) is a principal source of chromium for a variety of applications. It is an important starting material for chromium containing chemicals, such as chrome pigments, tanning agents, and wood preservatives.

The element chromium has chemical properties which make it attractive in several respects. It is an effective preservative for wood and leather; together with lead and other metals it forms brilliant pigments; and it offers excellent corrosion resistance. Despite its excellent properties, chromium poses serious problems. In its hexavalent oxidation state, it is one of the most objectionable water borne pollutants. It is highly carcinogenic and the discharge of chromium into air and water is scrutinized closely by OSHA and EPA. Trivalent chromium is not a proven carcinogen.

9.1.1 Demand

The sodium dichromate industry and its end markets are well established and mature. There are few prospects for rapid expansion and demand growth is expected to parallel GNP growth. Figure 9-1 illustrates sodium dichromate's inputs and end markets.

In order to depict the total demand for sodium dichromate, the conditions in its individual end markets are summarized below.

9.1.1.1 End Markets

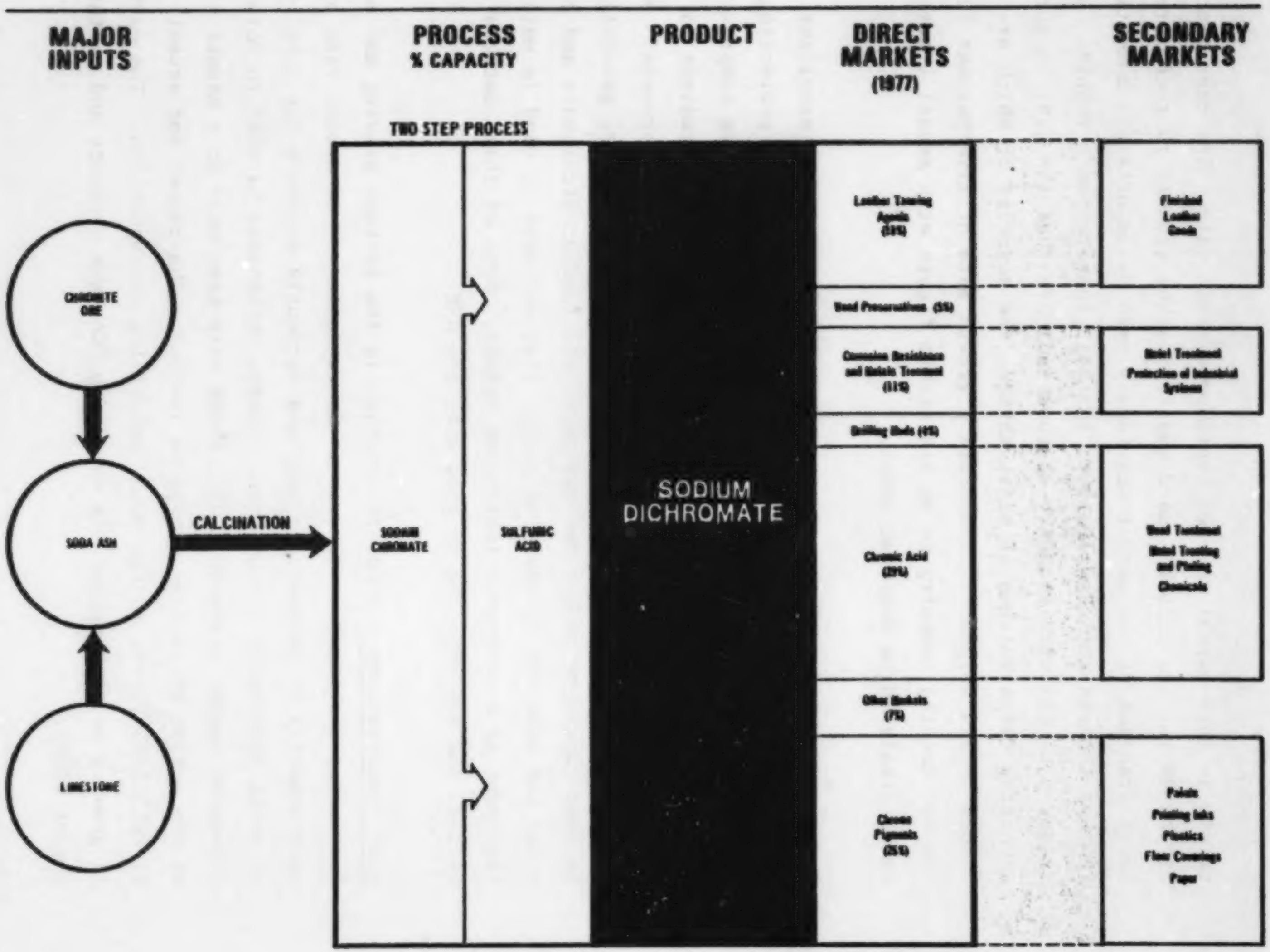
Chromic Acid - Chromic acid manufacturing consumes approximately 29 percent of current sodium dichromate production. Chromic acid is used primarily in metal treating and plating, which account for 80 percent of total output. In terms of cost effectiveness, consumer appeal, corrosion resistance, and ability to withstand wear and high tolerance machining, chrome plated components have few substitutes. Demand is, therefore, expected to remain stable in this segment of the market. There has been some fear that OSHA regulations concerning worker exposure to hexavalent chromium in plating shops would force a cutback in chromium plating. However, many of these fears have been dismissed by development of efficient systems for venting chromium vapors. Chromic acid is used also in wood treatment (ten percent of production) and in chemical manufacturing (five percent). The remaining five percent is consumed in miscellaneous uses.

Chrome Pigments - Approximately 26 percent of current dichromate production is used in manufacturing chrome pigments. These pigments are used primarily in paints, surface coatings, floor products, paper, and printing inks. The chrome pigments market is mature, and industry sources indicate that there will be zero growth or possibly declining demand in the future. This outlook is based in part upon fears that OSHA regulations concerning worker exposure to lead (most chrome pigments are lead chromates) will force smaller consumers of chrome pigments to switch to organic colors rather than install the equipment necessary to lower lead levels in the workplace.

Leather Tanning - Approximately 18 percent of sodium dichromate production is used in leather tanning. Sodium dichromate is converted to chromic sulfate and applied to the leather to inhibit chemical decomposition. This market has experienced significant fluctuations in demand in recent years. While shipments of sodium dichromate to domestic leather tanners are increasing at approximatley five percent per year,

FIGURE 9-1

SODIUM DICHROMATE:
INPUTS AND END MARKETS


MAJOR INPUTS
PROCESS % CAPACITY
PRODUCT
DIRECT MARKETS (1977)
SECONDARY MARKETS
CHROMITE ORE
SODA ASH
LIMESTONE
CALCINATION
TWO STEP PROCESS
SODIUM CHROMATE
SULFURIC ACID
SODIUM DICHROMATE
Leather Tanning Agents (21%)
Wood Preservatives (3%)
Corrosion Resistance and Metals Treatment (11%)
Drilling Muds (4%)
Chromic Acid (29%)
Other Markets (7%)
Chrome Pigments (25%)
Finished Leather Goods
Metal Treatment
Protection of Industrial Systems
Wood Treatment
Metal Treating and Plating
Chemicals
Paints
Printing Inks
Plastics
Floor Coverings
Paper

growth in this market may not continue at this rate. The depreciation of the dollar has allowed the domestic leather industry to recapture a large fraction of the market previously held by imports and domestic leather tanners anticipate growth in their industry as a result. However, recent contacts with industry sources indicate that the U.S. is currently exporting large volumes of hides abroad, the majority of which are not tanned before shipment. Therefore a growth rate of five percent for the leather tanning industry is an optimistic figure with actual growth rates likely to be somewhat lower.

Corrosion Resistance and Metals Treatment - Chromium has excellent corrosion inhibiting properties which make it useful for protecting industrial systems and treating metal. These two end uses comprise 11 percent of the sodium dichromate market. The active ingredient in protecting industrial systems from corrosion is sodium chromate. Sodium chromate can be purchased as a finished product. However, generally it is less expensive to buy the raw materials (sodium dichromate and caustic soda) and make the chromate in situ. Zinc chromate is used in metals treatment as a corrosion inhibiting primer. Both of these markets are mature, and are expected to grow with the GNP.

Wood Preservatives - Wood preservation is the fastest growing end market for sodium dichromate. The market is expanding at an annual rate of approximately 10 percent per year and currently accounts for five percent of total dichromate consumption. Sodium dichromate is used to form chromated copper arsenate (CCA), which acts upon wood in a manner similar to the action of tanning agents on leather. The copper and arsenic bind to cellulose fibers in the wood, inhibiting decomposition. The market is growing as wood preservers switch to CCA from creosote and pentachlorophenol (PCP).

Drilling Muds - The use of sodium dichromate in petroleum drilling muds also is growing fairly rapidly and currently accounts for four percent of the dichromate market. Drilling muds are formed of chromium ligno

sulfinates. These compounds are used to lubricate the tips of drill bits to facilitate their movement through stone, and to carry away stone chips from the bit head. Demand for these compounds has grown substantially with increased drilling activity in the U.S., and is expected to continue growing.

Other Markets - Other end uses of sodium dichromate include chrome chemicals, catalysts, and other miscellaneous uses. It appears that demand for dichromate in these end markets will remain stable.

9.1.1.2 Demand Summary

End markets for sodium dichromate generally are mature. Total demand growth is expected to be roughly two or three percent per year. Specific predictions and conditions in each end market are summarized below.

- **Chromic Acid - Principal use is in chrome plating; should track GNP growth - The major potential obstacle is OSHA regulation of worker exposure to hexavalent chromium, which could force closure of small plating shops.**
- **Chrome Pigments - End uses - paints, surface coatings, floor products, paper, and printing inks are all mature, and should experience no major changes in demand. OSHA regulation of worker exposure to lead in the production and use of chrome pigments may force some smaller users to switch to organic colors.**
- Leather Tanning - Use of chromic acid in leather tanning is expected to grow at a moderately fast pace due to strong demand for leather exports. This has been caused by the dollar's depreciation. However, many hides are being exported before tanning and growth of leather tanning may be less than expected.
- Corrosion Resistance and Metals Treatment - This market is mature, and demand should remain stable.
- Wood Preservatives - Demand for dichromate for use in wood preservatives is growing at 10 percent per year, and should continue to penetrate the markets of creosote and PCP.

- Drilling Muds - Increased domestic drilling activity is driving up demand for sodium dichromate in the production of drilling muds.

The greatest industry growth is in dichromate's smaller markets and, therefore, should not have a significant impact upon overall demand for the product. Most industry sources predict demand growth at two to three percent, barring any serious cutbacks in demand due to OSHA regulations.

9.1.2 Supply

9.1.2.1 Production

Sodium dichromate production has varied widely during the period 1968-1977, with changes as great as 30 percent during the recession years of 1974-1975. Total growth in production has been only 7.3 percent, which is equivalent to an annual growth rate of 0.79 percent. Part of the depressed growth rate from 1968 to 1977 was due to the severe drop in production in 1975, from which the industry has not yet recovered fully. The parallel between production and general economic conditions, indicates that the sodium dichromate industry is mature, and that its growth will tend to follow or trail GNP growth in the long run. Table 9-1 and Graph 9-1 summarize production and prices during the period 1968-1977.

9.1.2.2 Producers

There are three producers of sodium dichromate, each operating one plant. Two producers, Allied Chemical and Diamond Shamrock are integrated to soda ash as a raw material and to chromic acid as an end product. The third producer, PPG Industries, has no vertical integration. Table 9-2 summarizes current producers and facilities.

TABLE 9-1

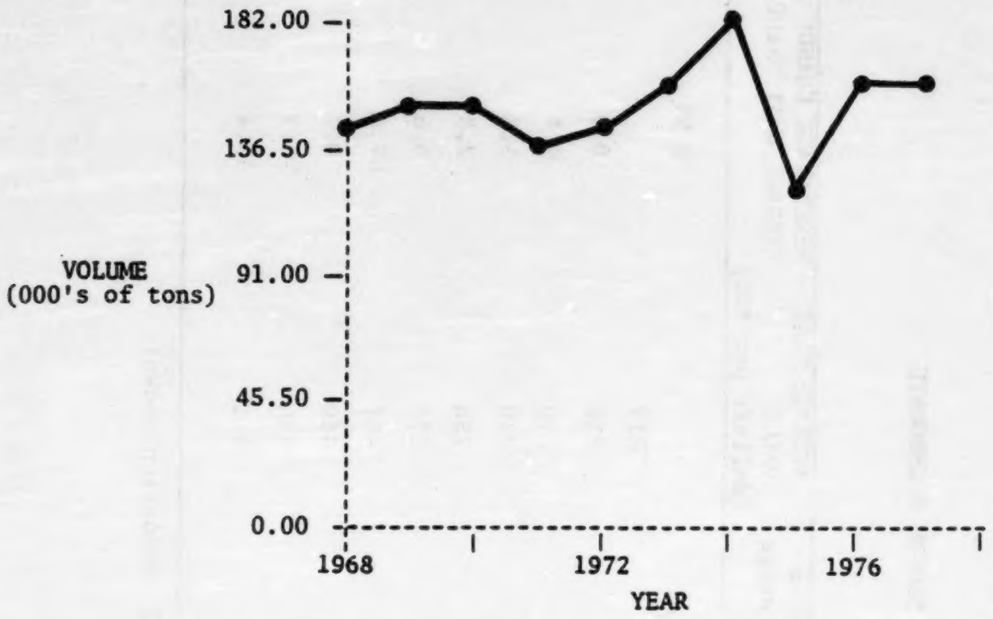
PRODUCTION OF SODIUM DICHROMATE

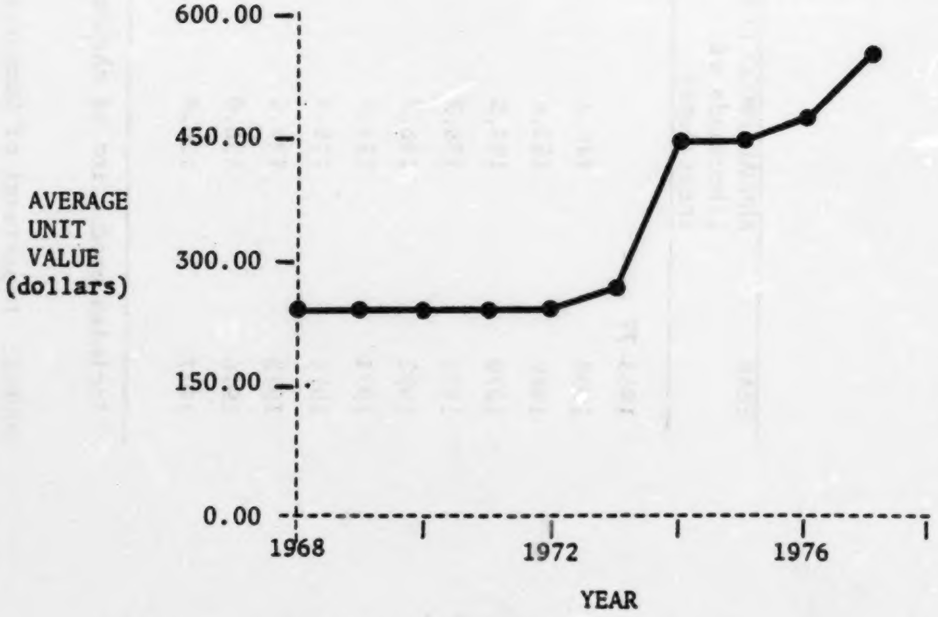
YEAR	ANNUAL PRODUCTION* (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGE UNIT VALUE (dollars per ton)	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1968-77		0.8%		9.9%
1968	146.1		$239	
1969	152.6	4.5	239	0.0
1970	153.5	0.6	240	0.4
1971	138.2	-10.0	249	3.8
1972	146.7	6.1	256	2.8
1973	158.7	8.2	273	6.6
1974	178.7	12.6	457	67.4
1975	124.5	-30.3	460	0.7
1976	156.9	25.9	486	5.7
1977	156.8	-0.1	561	15.4

* Includes production of chromate (about 4% of production shown).

SOURCE: Department of Commerce.

GRAPH 9-1
SODIUM DICHROMATE PRODUCTION AND PRICE





SOURCE: Department of Commerce

TABLE 9-2

PRODUCERS OF SODIUM DICHROMATE

COMPANY	LOCATION	ANNUAL CAPACITY (thousand tons)	ESTIMATED PERCENTAGE OF INDUSTRY CAPACITY	INTEGRATION	
				RAW MATERIALS	END PRODUCTS
Allied Chemical Company	Baltimore, MD	65.0	36	Soda Ash	Chromic Acid
Diamond Shamrock	Castle Hayne, NC	84.2	47	Soda Ash	Chromic Acid
PPG Industries, Inc.	Corpus Christie, TX	30.0	17		
TOTAL		179.2	100		

SOURCE: Chemical Marketing Reporter, July 12, 1976.

9.1.2.3 Process

Production of sodium dichromate is a two stage process. The first stage is the production of sodium chromate by calcining a mixture of chromite ore, soda ash, and limestone. In the second stage, sodium dichromate is produced by the reaction of sodium chromate and sulfuric acid. Sodium sulfate is produced as a by-product of the second stage reaction. (See Table 9-3 for estimates of raw material requirements and manufacturing costs.)

The production process is governed by the following reactions:

1) $4(FeO \cdot Cr_2O_3) + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$
(Formation of sodium chromate)

2) $2Na_2CrO_4 + H_2SO_4 \rightarrow Na_2Cr_2O_7 + H_2O + Na_2SO_4$
(Formation of the dichromate)

9.1.3 Competition

Sodium dichromate is a principal starting material for a variety of processes which result in products containing chromium. In this role, dichromate has few substitutes except for sodium chromate, which is produced in the first stage of the dichromate production process. Sodium chromate generally is more expensive than sodium dichromate.

The main form of competition in sodium dichromate use is end market competition. The primary substitutes and the nature of competition in dichromate's major end markets are summarized below.

9.1.3.1 End Market Competition

Chrome Plating - There are two submarkets in the chrome plating industry: hard chrome plating and decorative chrome plating. Hard chrome plating provides hardness, low friction, and long wear in industrial applications.

TABLE 9-3a

ESTIMATED COST OF MANUFACTURING SODIUM DICHROMATE*
(mid-1978 dollars)

Plant Capacity	28,700 tons/year
Annual Production	22,000 tons/year (77% capacity utilization)
Fixed Investment	$8.7 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Chromite Ore ($50\%\ Cr_2O_3$)	2199 lb	.031	68.20
- Soda Ash	1601 lb	.034	54.40
- Limestone	2999 lb	.023	69.00
- Sulfuric Acid (66 Bé)	900 lb	.016	14.40
• Utilities			
- Power	500 kWh	.03	15.00
- Fuel	19.5 Btu	2.50	48.80
- Steam	6.0 klb	3.25	19.50
- Process Water	14.1 kgal	.75	10.60
Total Variable Costs			$299.90
SEMI-VARIABLE COSTS			
• Labor			88.10
• Maintenance			15.80
Total Semi-Variable Costs			$103.90
FIXED COSTS			
• Plant Overhead			22.00
• Depreciation			39.50
• Taxes & Insurance			5.90
Total Fixed Costs			$ 67.40
BYPRODUCT CREDIT			
• Sodium Sulfate (anhydrous)	1200	.027	(32.40)
TOTAL COST OF MANUFACTURE			$438.80

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 9-3b

ESTIMATED COST OF MANUFACTURING SODIUM DICHROMATE*
(mid-1978 dollars)

Plant Capacity	71,700 tons/year
Annual Production	55,000 tons/year (77% capacity utilization)
Fixed Investment	$15.8 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Chromite Ore (50% Cr_2O_3)	2199 lb	.031	68.20
- Soda Ash	1601 lb	.034	54.40
- Limestone	2999 lb	.023	69.00
- Sulfuric Acid (66 Be´)	900 lb	.016	14.40
• Utilities			
- Power	500 kWh	.03	15.00
- Fuel	19.5 Btu	2.50	48.80
- Steam	6.0 klb	3.25	19.50
- Process Water	14.1 kgal	.75	10.60
Total Variable Costs			$299.90
SEMI-VARIABLE COSTS			
• Labor			51.20
• Maintenance			11.40
Total Semi-Variable Costs			$ 62.60
FIXED COSTS			
• Plant Overhead			12.80
• Depreciation			28.70
• Taxes & Insurance			4.30
Total Fixed Costs			$ 45.80
BYPRODUCT CREDIT			
• Sodium Sulfate (anhydrous)	1200 lb	.027	(32.40)
TOTAL COST OF MANUFACTURE			$375.90

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 9-3c

ESTIMATED COST OF MANUFACTURING SODIUM DICHROMATE*
(mid-1978 dollars)

Plant Capacity	100,300 tons/year
Annual Production	77,000 tons/year (77% capacity utilization)
Fixed Investment	$19.6 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Chromite Ore (50% Cr_2O_3)	2199 lb	.031	68.20
- Soda Ash	1601 lb	.034	54.40
- Limestone	2999 lb	.023	69.00
- Sulfuric Acid (66 Bé)	900 lb	.016	14.40
• Utilities			
- Power	500 kWh	.03	15.00
- Fuel	19.5 Btu	2.50	48.80
- Steam	6.0 klb	3.25	19.50
- Process Water	14.1 kgal	.75	10.60
Total Variable Costs			$299.90
SEMI-VARIABLE COSTS			
• Labor			41.10
• Maintenance			10.20
Total Semi-Variable Costs			$ 51.30
FIXED COSTS			
• Plant Overhead			10.20
• Depreciation			25.40
• Taxes & Insurance			3.80
Total Fixed Costs			$ 39.40
BYPRODUCT CREDIT			
• Sodium Sulfate (anhydrous)	1200 lb	.027	(32.40)
TOTAL COST OF MANUFACTURE			$358.20

SOURCE: Contractor and EEA estimates

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*See Appendix C

In this area, there are no direct substitutes. Both iron and electroless nickel (a plating process using a chemical catalyst rather than electrical current) can be plated for industrial applications, but neither offers comparable performance characteristics, and electroless nickel is much more expensive. In decorative applications, chrome plating has the advantages of cost effectiveness, consumer appeal, and strong corrosion resistance, all of which contribute to its strength in this market. Plastics and painted materials offer some competition in automobile interiors and other uses.

Chrome Pigments - The chrome pigments industry may face serious competition from organic colors. Some small pigment consumers may be covered by OSHA regulations further limiting worker exposure to lead. The cost of implementing these regulations may force these consumers to switch to organic substitutes. Increased switching to organic colors may also result as chrome pigments manufacturers attempt to pass through their increased OSHA regulatory costs by raising pigment prices. Thus, OSHA regulations may directly or indirectly stimulate a shift from inorganic pigments to organic coloring agents.

Tanning - There is no widely accepted substitute to chromic sulfate in leather tanning. Synthetic and vegetable tanning agents are limited to certain product uses and chromic sulfate has wider applicability.

Wood Preservatives - There are three commonly used wood preservatives: chromated copper arsenate (CCA), creosote, and pentachlorophenol (PCP). These three products are often interchangeable in industrial applications. CCA is preferred for interior uses and home applications. Creosote is a black, sticky product derived from coal tar. It cannot be painted, and is of little use in interior applications. PCP-treated wood cannot be used in closed spaces as it emits toxic vapors.

Drilling Muds - Many mineral compounds can be substituted for chromium drilling muds. The chrome muds, however, are more cost effective than prevalent substitutes.

Metals Treatment and Corrosion Inhibition - Chromium corrosion inhibitors have few cost effective substitutes in industrial applications. Zinc compounds are used for metal treatment, but are less cost effective than chromium and have a strong white color.

Imports are no longer a factor in the sodium dichromate market. As recently as 1971, imports were an important aspect of the market. However, increases in ocean shipping rates and the depreciation of the dollar have made imported dichromate noncompetitive. The United States currently is a net exporter of sodium dichromate.

9.1.4 Economic Outlook

9.1.4.1 Revenue

Sodium dichromate sales are expected to grow zero to five percent annually. The most pessimistic prediction is based on the assumption that OSHA regulations will cause a drop in consumption in the chrome pigments and chromic acid end markets. The most favorable prediction assumes that this will not occur, and that the smaller markets of tanning, wood preservatives, and drilling muds will continue to grow at a fairly rapid pace. Most predictions are for a growth rate of two percent.

Diamond Shamrock plans to expand capacity from 240 tons/day to 300 tons/day during the 1980's. This represents an 11 percent increase in industry capacity, and has the potential for lowering capacity utilization in the industry if demand growth remains sluggish.

9.1.4.2 Manufacturing Costs

Considerable uncertainty exists with respect to future manufacturing costs for sodium dichromate. The chromite ore used in chemicals manufacturing is imported almost entirely from South Africa. There is some potential for political instability in this region, which could disrupt supplies and drive up the price. The price rose considerably during the embargo imposed on Rhodesian ore in 1977, but subsequently leveled off and has not changed substantially since the embargo was lifted in 1980.

The price of soda ash has declined due to an increase in the production of natural soda ash in the western United States.

Sulfuric acid, another major input, has increased in price rapidly over the last five years. Prices for this commodity are expected to continue their strong rise.

Energy is a comparatively small input, and while it is expected to contribute to cost increases, it should not have an overwhelming impact.

Total production costs for sodium dichromate can be expected to climb in the future. The rate of increase, however, should not be as great as that for the chemical industry in general.

9.1.4.3 Profit Margins

Demand growth for sodium dichromate is expected to be moderate (2-3 percent) during the next several years. This prediction, however, is based primarily on the maturity of dichromate's end markets, rather than on competition from substitute products. Sodium dichromate has relatively secure end markets, and relatively few substitutes in them.

Moderate cost increases are likely to be reflected in the product price, and profit margins in this industry should remain secure.

9.1.5 Characterization Summary

Sodium dichromate is an effective preservative for wood and leather, an ingredient in pigments used in paints, and a corrosion inhibitor. Approximately 157,000 tons were produced in 1977 by three companies: Allied Chemical, Diamond Shamrock, and PPG. Substantial demand growth is anticipated in some of sodium dichromate's end markets, particularly wood preservatives. However, because the highest growth rates will occur in dichromate's smaller markets, the overall demand growth for the product will be slow to moderate. Industry observers cite possible OSHA regulations of worker exposure to hexavalent chromium as a potential threat to growth in dichromate's main market, chromic acid. If demand cutbacks due to OSHA regulations are not severe, growth of the sodium dichromate industry should be 2 to 3 percent annually.

9.2 IMPACT ANALYSIS

This section analyzes the potential economic impacts of requiring the sodium dichromate subcategory to comply with BAT effluent control standards. All sodium dichromate manufacturers are currently complying with the BPT effluent limitations promulgated and in effect for this subcategory. For this subcategory, BAT is equivalent to BPT. Since there will be no incremental costs above BPT required for compliance with BAT regulations, effluent regulations will have no impacts on the sodium dichromate subcategory.

9.2.1 Pollution Control Technology and Costs

As noted above, no new pollution control costs will be incurred by the sodium dichromate subcategory. Capital and operating costs, developed by the technical contractor for pollution control equipment designed to meet BPT levels of waste removal, are shown in Table 9-4.

The major waste in sodium dichromate manufacture is the undigested portion of the chromite ore. To achieve BPT removal levels, the following procedure is used:

- Sodium bisulfide and caustic soda are added to the wastewater to reduce hexavalent chromium, and to precipitate toxic metals and chromium hydroxide.
- Solids are settled in lagoons, where additional sodium bisulfide is added.
- Overflow from the clarifier is pH adjusted and discharged. Underflow is returned to the lagoon.

Pollution control cost estimates were developed for three model plant sizes, with average production rates of 22,000, 55,000 and 77,000 tons per year. For the model plants, an average unit wastewater flow of 1,625 gallons per ton (7mg/kkg) was assumed. Pollution control costs for the model plants are summarized in Table 9-4.

TABLE 9-4: POLLUTION CONTROL COSTS

Chemical: Sodium Dichromate

Model Plant Production (tons/year)	BPT		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
22,000	$1,391,197	$255,756	For this subcategory, BAT is the same as BPT. There are no incremental costs over BPT for compliance with BAT regulations.	
55,000	2,733,930	446,001		
77,000	3,649,938	573,892		

Source: Technical Contractor

10. TITANIUM DIOXIDE

10.1 CHARACTERIZATION

Titanium dioxide (TiO_2) is a white pigment used to whiten or opacify paints, paper, plastics, and several other products. It is used more than other white pigments because of its exceptional hiding power, negligible color, and inertness. Titanium dioxide is a high volume chemical ranking 49th in terms of production volume for all U.S. chemicals. It is also a high value commodity with recent prices around $1,000 per ton (many chemicals are worth one-tenth this much). Because of its high value, TiO_2 can be shipped internationally, making foreign competition a significant characteristic of the U.S. market.

Titanium dioxide is a well established, mature product having been produced for over 40 years. Most of its many end markets are also mature, and product demand has paralleled GNP growth. Although the chemical has been produced for many years, relatively recent technological advances have reduced manufacturing costs.

10.1.1 Demand

Over one-half of the titanium dioxide produced is used in paints, varnishes, and lacquers. Almost a third is used in paper and plastics. Other uses are found in ceramics, ink, and rubber (see Figure 10-1).

Production of titanium dioxide is particularly dependent on the use of paint and coatings in housing starts and restoration and in automobile manufacture. In 1975, demand for paint and coating products slipped well below the 1974 level. As a result, paint and coating manufacturers reduced their output as well as their purchases of titanium dioxide. In addition, they used inventories accumulated in anticipation of a shortage and cut the proportion of titanium dioxide used in trade paints (to avoid raising paint prices). Reduction of hiding power was exchanged for lower prices. The paper industry followed the same pattern. Both industries have recovered somewhat and the titanium dioxide content has been increasing again. In paper especially, TiO_2 can improve the quality of coated materials and save weight.

U.S. demand for TiO_2 is increasing and slowly shifting. Forecasts show a long run growth rate of about three percent. Surface coatings will continue to dominate TiO_2's market, but growth in other areas will be faster than that in coatings. The use of TiO_2 in plastic, for example, is expected to grow about eight percent per year and use in paper, about five percent. Overall, TiO_2 has mature markets and its long run increase in volume is expected to follow real GNP growth.

10.1.2 Supply

10.1.2.1 Production

Production of TiO_2 grew steadily between 1964 and 1974 at an average rate of 3.25 percent per year. The last several years, however, have seen highly variable demand (and thus production). In 1975, a recession year, production fell 23 percent. This is indicative of TiO_2's dependence on general economic conditions. Production rose in 1976, but was still below the peak production in 1973-74 (see Table 10-1 and Graph 10-1). In 1977, production fell again to a level 14 percent below the peak year of 1974. In 1978, production rose 5 percent above 1977 levels to 720,000 tons.

10.1.2.2 Producers

There are six producers of TiO_2 at 11 plant sites in the United States (see Table 10-2). DuPont controls 55 percent of the total industry

FIGURE 10-1

TITANIUM DIOXIDE:
INPUTS AND END MARKETS

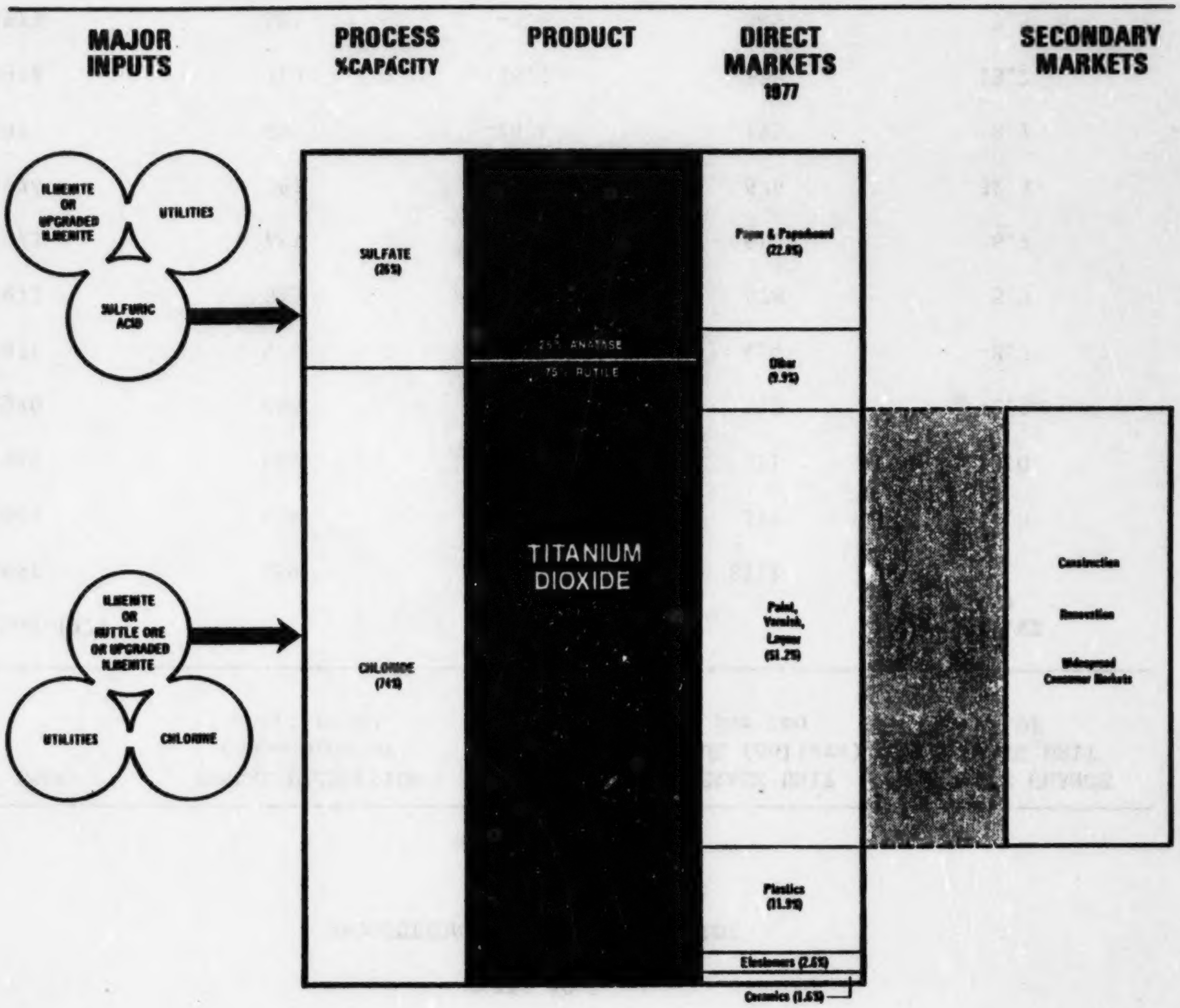

MAJOR INPUTS
PROCESS %CAPACITY
PRODUCT
DIRECT MARKETS 1977
SECONDARY MARKETS
ILMENITE OR UPGRADED ILMENITE
UTILITIES
SULFURIC ACID
ILMENITE OR RUTTLE ORE OR UPGRADED ILMENITE
UTILITIES
CHLORINE
SULFATE (26%)
CHLORIDE (74%)
25% ANATASE
75% RUTILE
TITANIUM DIOXIDE
Paper & Paperboard (22.8%)
Other (9.9%)
Paint, Varnish, Laquer (51.2%)
Plastics (11.9%)
Elastomers (2.6%)
Ceramics (1.6%)
Construction
Renovation
Widespread Consumer Markets

TABLE 10-1

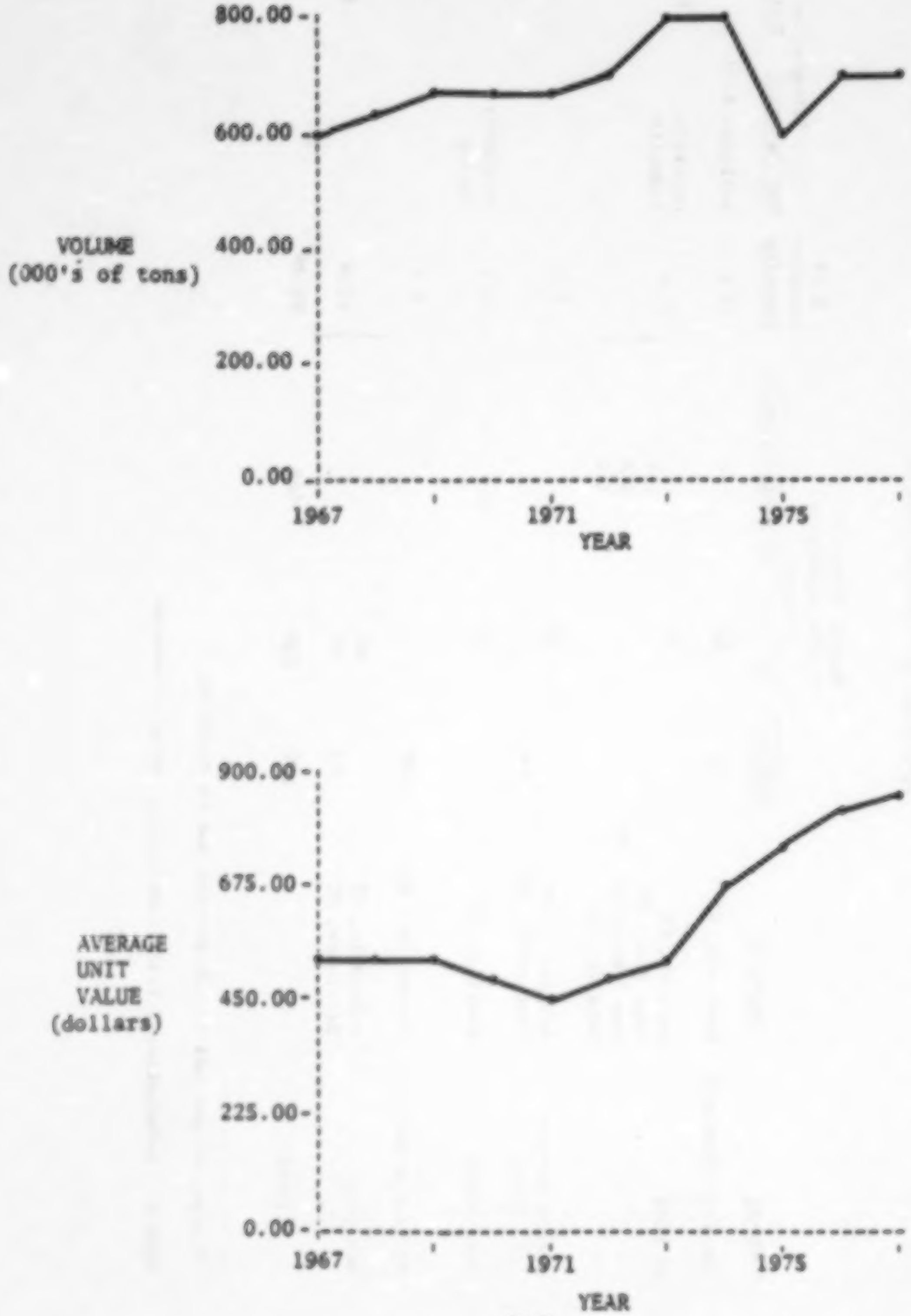
PRODUCTION OF TITANIUM DIOXIDE

YEAR	ANNUAL PRODUCTION (thousands of short tons)	GROWTH RATE (percent change per year)	AVERAGÉ UNIT VALUE (dollars) per ton	PERCENTAGE CHANGE IN AVERAGE UNIT VALUE
1967–1977		1.6%		5.4%
1967	589		$511	
1968	624	5.9	511	0.0
1969	664	6.4	511	0.0
1970	665	-1.4	497	-2.7
1971	678	3.5	454	-8.7
1972	693	2.2	478	5.3
1973	785	13.3	510	6.7
1974	787	0.3	676	32.5
1975	603	-24.4	735	8.7
1976	713	18.2	836	13.7
1977	687	-3.6	865	3.5

SOURCE: Department of Commerce.

GRAPH 10-1

TITANIUM DIOXIDE PRODUCTION AND PRICE



SOURCE: Department of Commerce

TABLE 10-2

PRODUCERS OF TITANIUM DIOXIDE

		Annual Capacity (1,000 tons/year) Process			% of Industry	Integration	
Company	Location	Sulfate	Chloride	Chloride-Ilmenite	Capacity	Raw Material	End-Product
American Cyanamid	Savannah, GA	72	40	--	10.6	Sulfuric Acid	
Du Pont	Antioch, CA		30		54.6	Chlorine Ilmenite	Paint
	Edge Moor, DE			167			
	New Johnsville, TN			228			
	DeLisle, MI			150			
Gulf & Western (NJ Zinc)	Ashtabula, OH		35		7.5		
	Gloucester, NJ	44					
Kerr McGee	Hamilton, MI		50		4.7	Synthetic Rutile	
NL Industries	Sayreville, NJ	100			9.5		Paint
SCM Corp.	Ashtabula, OH		42		13.0		Paint
	Baltimore, MD	53	42				
TOTAL		269	239	545	99.9*		

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*Figures do not add to 100 percent due to rounding.

SOURCE: International Trade Commission, Industry Sources capacity with the next three producers accounting for another one-third. Most of the producers are large chemical corporations or conglomerates. There is a considerable amount of forward integration by the producers to the main end product, paint. Backward integration has actually decreased in some cases as TiO_2 producers have sold their ore interests. Kerr McGee has a synthetic rutile ore plant in Mobile, Alabama which resumed operation in 1980 after a two-year shutdown for additions and improvements to the plant's equipment. (Kerr McGee 10 K Report, 1979).

The total industry capacity is over one million tons per year with individual plant capacities ranging in size from 30,000 to 228,000 tons/year. Titanium dioxide is produced by the sulfate, chloride or chloride-ilmenite process. Of the three processes, sulfate plants account for 269,000 tons (25 percent) of the total industry capacity, chloride plants account for 239,000 tons (23 percent), and chloride-ilmenite plants account for 545,000 tons (52 percent). The newer plants all utilize the chloride process in part because of the higher pollution control costs associated with sulfate production.

The four sulfate plants range in age from 23 to 44 years. All four plants are completely dedicated to titanium dioxide production. Thus, except for some sulfuric acid plants at the facilities (used in TiO_2 production), there are no other chemicals produced. The startup dates for the plants are:

- NL - Sayreville: 1935
- NJ Zinc - Gloucester: late 1940's
- American Cyanamid - Savannah: 1955
- SCM - Baltimore: 1956

Capacity has been expanding steadily in the industry. Before 1971 there was an oversupply of TiO_2 in the market, in 1973 and 1975 a shortage, and more recently, oversupply. In the past decade, DuPont has more than doubled the capacity at its New Johnsonville, Tennessee plant. Recently, the chloride-ilmenite capacity at its Edge Moor, Delaware plant was tripled as the last of DuPont's sulfate plants was shut down (a 155,000 ton/year unit in Edge Moor). DuPont has a new 150,000 ton/year chloride plant partially on stream in DeLisle, Mississippi. (The plant is not expected to be operating at capacity until 1982.) They also are interested in building a unit the size of the DeLisle plant in Europe.

10.1.2.3 Process

There are three ways of making TiO_2: by the chloride process, by the chloride-ilmenite process or by the sulfate process. There are also two basic types of TiO_2 crystals produced: rutile and anatase. The rutile form of the pigment normally results from the chloride process and the anatase pigment from the sulfate process. All three processes can now produce both types of pigment although there are subtle differences between the pigments.

10.1.2.3.1 Sulfate Process

The sulfate process is the older process which uses sulfuric acid to digest titanium ores. The ore used in this process is either ilmenite (40 percent to 55 percent TiO_2) or an upgraded ilmenite (70 to 85 percent). Naturally, when dealing with an ore which contains only 50 percent product, there are significant waste products. The reactions are:

$$FeTiO_3 + 2H_2SO_4 \rightarrow FeSO_4 + TiO''SO_4 + 2H_2O$$

$$TiO''SO_4 + 2H_2O \rightarrow TiO_2''H_2O + H_2SO_4$$

$$TiO_2''H_2O \xrightarrow{heat} TiO_2 + H_2O$$

The iron content of the ilmenite dissolves as ferric sulfate and is converted to ferrous sulfate through the addition of scrap iron. Many other metals which may have been in the ore also dissolve as sulfates. The result is a waste stream which may contain three to four tons of hydrated iron sulfate and 40 tons of dilute sulfuric acid and wash water for each ton of product. The acid stream may be neutralized using limestone. This, in turn, results in approximately four tons of gypsum (calcium sulfate) for each ton of product. There are markets for the gypsum (e.g., wallboard manufacture) but its price is low.

The estimated manufacturing costs for sulfate TiO_2 production are given in Table 10-3. Included are material requirements for producing one short ton of TiO_2.

10.1.2.3.2 Chloride Process

In the chloride process, first used in the late 1950's, an ore high in titanium and low in iron is chlorinated in a fluidized bed. Rutile, synthetic rutile, or upgraded ilmenite are generally used. The reactions for the chloride process are:

$$3TiO_2 + 4C + 6Cl_2 \rightarrow 3TiCl_4 + 2CO + 2CO_2$$

$$TiCl_4 + O_2 \rightarrow TiO_2 + 2Cl_2$$

(94 percent yield based on titanium)

The estimated manufacturing costs for chloride TiO_2 production are presented in Table 10-4. Included are material requirements for producing one short ton of TiO_2.

10.1.2.3.3 Chloride-Ilmenite Process

The chloride-ilmenite process is a proprietary process developed by DuPont. This process utilizes lower grade ilmenite ores which are cheaper and more available than the ilmenite and rutile ores used in the chloride process described above. Therefore, DuPont has a significant cost advantage as a result of using the chloride-ilmenite process.

10.1.3 Competition

10.1.3.1 The Titanium Dioxide Pigments

Titanium dioxide pigments are produced in many forms. Starting with either the rutile crystal (the denser form) or the anatase crystal, a great variety of coatings and other additives can be used to make the pigment perform best in any particular end use. In addition to the chemical differences in pigments, the form of the product also varies. About 20 percent of TiO_2 in 1978 was shipped in a slurry rather than in its usual powdered form. Because of these differences in pigment characteristics, the TiO_2 market is really segmented into several submarkets depending on the end use. However, manufacturers can switch production among several grades of pigments so there is competition in each submarket (based predominantly on price). In 1973, when there was a TiO_2 shortage, availability, as well as price, became an important competitive factor. More recently there has been excess capacity and availability has not been a major factor.

10.1.3.2 The World Market

Titanium dioxide is a high value commodity used throughout the world. Because of its very high unit value (around $1,000/ton), it can be economical to ship it internationally. In the United States, foreign trade has played an important role (see Table 10-5). Net imports have been growing since 1975 and presently represent nearly 15 percent of consumption. This is unusually high for a U.S. process chemical. SCM Corporation filed a complaint with the Treasury Department in September of 1978, alleging that imports from Belgium, West Germany, the United Kingdom, and France have been sold at less than fair market value. The

TABLE 10-3a

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - SULFATE PROCESS*
(mid-1978 dollars)

Plant Capacity	46,000 tons/year
Annual Production	35,000 tons/year (76% capacity utilization)
Fixed Investment	$84.2 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ilmenite Ore	1.95 tons	37.80	73.70
- Sulfuric Acid	4.13 tons	20.06	82.80
- Scrap Iron	.16 tons	108.00	162.30
• Utilities			
- Cooling Water	102.3 mgal	.031	3.20
- Steam	23.26 mlb	2.83	65.80
- Process Water	26.74 mgal	.41	11.00
- Electricity	514.8 kWh	.019	9.80
- Natural Gas	9.6 MMBtu	2.18	20.90
Total Variable Costs			$446.80
SEMI-VARIABLE COSTS			
• Labor			115.90
• Maintenance			53.00
Total Semi-Variable Costs			$168.90
FIXED COSTS			
• Plant Overhead			81.90
• Depreciation			240.00
• Taxes & Insurance			448.00
Total Fixed Costs			$369.90
TOTAL COST OF MANUFACTURE			$985.60

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-3b

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - SULFATE PROCESS*
(mid-1978 dollars)

Plant Capacity	69,000 tons/year
Annual Production	52,500 tons/year (76% capacity utilization)
Fixed Investment	$111.8 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ilmenite Ore	1.95 tons	37.80	73.70
- Sulfuric Acid	4.13 tons	20.06	82.80
- Scrap Iron	.16 tons	108.00	17.30
- Other			162.30
• Utilities			
- Cooling Water	102.3 mgal	.031	3.20
- Steam	23.26 mlb	2.83	65.80
- Process Water	26.74 mgal	.41	11.00
- Electricity	514.8 kWh	.019	9.80
- Natural Gas	9.6 MMBtu	2.18	20.90
Total Variable Costs			$446.80
SEMI-VARIABLE COSTS			
• Labor			86.60
• Maintenance			45.60
Total Semi-Variable Costs			$132.20
FIXED COSTS			
• Plant Overhead			95.10
• Depreciation			212.80
• Taxes & Insurance			42.50
Total Fixed Costs			$350.40
TOTAL COST OF MANUFACTURE			$929.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-3c

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - SULFATE PROCESS*

(mid-1978 dollars)

Plant Capacity	108,000 tons/year
Annual Production	82,000 tons/year (76% capacity utilization)
Fixed Investment	$153 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Ilmenite Ore	1.95 tons	37.80	73.70
- Sulfuric Acid	4.13 tons	20.06	82.80
- Scrap Iron	.16 tons	108.00	17.30
- Other			162.30
• Utilities			
- Cooling Water	102.3 mgal	.031	3.20
- Steam	23.26 mlb	2.83	65.80
- Process Water	26.74 mgal	.41	11.00
- Electricity	514.8 kWh	.019	9.80
- Natural Gas	9.6 MMBtu	2.18	20.90
Total Variable Costs			$446.80
SEMI-VARIABLE COSTS			
• Labor			61.90
• Maintenance			39.50
Total Semi-Variable Costs			$101.40
FIXED COSTS			
• Plant Overhead			131.50
• Depreciation			186.40
• Taxes & Insurance			37.30
Total Fixed Costs			$355.20
TOTAL COST OF MANUFACTURE			$903.40

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-4a

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - CHLORIDE PROCESS*
(mid-1978 dollars)

Plant Capacity	24,200 tons/year
Annual Production	18,500 tons/year (77% capacity utilization)
Fixed Investment	$36.5 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Rutile Ore	1.06 tons	270.00	286.20
- Metallurgical Coke	.26 tons	100.30	26.10
- Chlorine	.14 tons	130.40	18.30
- Oxygen	.5 tons	20.06	10.00
- Other			56.80
• Utilities			
- Cooling Water	120 mgal	.031	3.70
- Steam	10.25 mlb	5.67	58.10
- Process Water	7.5 mgal	.41	3.10
- Electricity	920 kWh	.019	17.50
- Other			2.40
Total Variable Costs			$482.20
SEMI-VARIABLE COSTS			
• Labor			143.80
• Maintenance			40.30
Total Semi-Variable Costs			$184.10
FIXED COSTS			
• Plant Overhead			104.20
• Depreciation			196.20
• Taxes & Insurance			39.20
Total Fixed Costs			$339.60
TOTAL COST OF MANUFACTURE			$1,005.90

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-4b

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - CHLORIDE PROCESS*

(mid-1978 dollars)

Plant Capacity	36,400 tons/year
Annual Production	28,000 tons/year (77% capacity utilization)
Fixed Investment	$48.6 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Rutile Ore	1.06 tons	270.00	286.20
- Metallurgical Coke	.26 tons	100.30	26.10
- Chlorine	.14 tons	130.40	18.30
- Oxygen	.5 tons	20.06	10.00
- Other			56.80
• Utilities			
- Cooling Water	120 mgal	.031	3.70
- Steam	10.25 mlb	5.67	58.10
- Process Water	7.5 mgal	.41	3.10
- Electricity	920 kWh	.019	17.50
- Other			2.40
Total Variable Costs			$482.20
SEMI-VARIABLE COSTS			
• Labor			109.40
• Maintenance			35.50
Total Semi-Variable Costs			$144.90
FIXED COSTS			
• Plant Overhead			96.80
• Depreciation			173.50
• Taxes & Insurance			33.60
Total Fixed Costs			$303.90
TOTAL COST OF MANUFACTURE			$931.00

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-4c

ESTIMATED COST OF MANUFACTURING TITANIUM DIOXIDE - CHLORIDE PROCESS*
(mid-1978 dollars)

Plant Capacity	65,000 tons/year
Annual Production	50,000 tons/year (77% capacity utilization)
Fixed Investment	$72.9 million

VARIABLE COSTS	Unit/Ton	$/Unit	$/Ton
• Materials			
- Rutile Ore	1.06 tons	270.00	286.20
- Metallurgical Coke	.26 tons	100.30	26.10
- Chlorine	.14 tons	130.40	18.30
- Oxygen	.5 tons	20.06	10.00
- Other			56.80
• Utilities			
- Cooling Water	120 mgal	.031	3.70
- Steam	10.25 mlb	5.67	58.10
- Process Water	7.5 mgal	.41	3.10
- Electricity	920 kWh	.019	17.50
- Other			2.40
Total Variable Costs			$482.20
SEMI-VARIABLE COSTS			
• Labor			78.90
• Maintenance			29.90
Total Semi-Variable Costs			$108.80
FIXED COSTS			
• Plant Overhead			102.00
• Depreciation			145.60
• Taxes & Insurance			29.20
Total Fixed Costs			$276.80
TOTAL COST OF MANUFACTURE			$867.80

SOURCE: Contractor and EEA estimates

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*See Appendix C

TABLE 10-5

TITANIUM DIOXIDE: U.S. PRODUCTION, FOREIGN TRADE, PRODUCER'S STOCKS AND APPARENT CONSUMPTION, 1973-77, JANUARY - JUNE 1977 AND JANUARY - JUNE 1978

Period	Production	Exports	Imports	End-of-period producers' stocks	Consumption	Ratio of imports to consumption
	Short tons	Short tons	Short tons	Short tons	Short tons	Percent
1973-------	784,996	20,554	60,419	40,508	1/ 850,622	7.1
1974-------	786,672	30,379	34,996	91,621	740,176	4.7
1975-------	603,429	15,676	26,502	106,963	598,913	4.4
1976-------	712,940	20,555	68,816	113,873	754,291	9.1
1977-------	678,699	16,225	114,810	113,839	781,318	14.7
January-June--						
1977-----	334,783	8,642	51,336	88,377	402,973	12.7
1978-----	356,986	10,805	62,834	83,019	438,835	14.3

1/ Stocks held at producing plants in December 1972 amounted to 66,269 short tons.

SOURCE: International Trade Commission, Department of Commerce.

International Trade Commission (ITC) was then asked by the Treasury Department to determine if there was a reasonable indication of injury or the likelihood of injury to an industry in the U.S. The commission decided, in November of 1978, that there was such an indication and that the Treasury Department's investigation should not be terminated. This finding indicated, at a minimum, that imported pigment is competitive with domestic pigment. A subsequent investigation resulted in a decision by the ITC in November of 1979 that the U.S. industry is not being injured by titanium dioxide imported from Europe.

World capacity for TiO_2 was about 2.4 million metric tons in 1978. Western Europe accounts for the greatest share (46 percent) followed by the U.S. and Canada (37 percent), Japan (9 percent), and other non-Communist countries (8 percent). Because TiO_2 consumption closely follows general economic conditions in each country, the demand varies by country as some economies outpace others. In the U.S., for example, weak European markets generally cause an increase in imports. Historically, as European capacity utilization has fallen, their exports have increased. Conversely, as European demand increases, their exports to the U.S. decrease.

10.1.3.3 The U.S. Market

There are six producers of TiO_2 in the U.S. with DuPont accounting for 55 percent of capacity (including their new Mississippi plant). There have been several plant closings since 1969 with NL's St. Louis sulfate process plant the most recent (June 1978). DuPont has closed down its sulfate plants and greatly expanded its chloride-ilmenite process capacity. Other plants have been expanded or sold since 1969. The net result of these changes was insufficient capacity in 1973, and overcapacity in 1977 and 1978. With overcapacity and especially rapid cost increases occurring simultaneously, profit margins were reduced.

Since TiO_2 competes predominantly on the basis of price, the pricing practices of the industry are the best indicators of the competitive stature of the industry. Given a certain level of demand, the two main factors influencing U.S. market price are the price of imports and the price set by the lowest cost domestic producer. The International Trade Commission (ITC) initially found some evidence of sales lost to European competitors, although the commission eventually ruled that the U.S. industry is not being injured by imports. In the long run, foreign producers could increase their market share if they could consistently underprice U.S. producers. According to the ITC study, some import prices in 1977 and 1978 were below and some above those of domestic producers. However, some sources consider the pricing of foreign pigment of secondary importance to the prices set by DuPont. One ITC commissioner, dissenting with the ITC's initial finding of injury, said,

> "DuPont is clearly the dominant firm in the domestic industry, with about half of domestic production and a unique chloride production process which is much more efficient than any other in the world. DuPont's profits are at reasonable levels and it plans major capacity expansions. I have not found much evidence of injury in the factors analyzed, but I am convinced that any injury which may exist is not by reason of imports from these four countries, but is more likely related to conditions of competition among domestic producers."

Thus, the U.S. market prices are delineated by DuPont as the lowest cost producer setting a floor, and import prices limiting the ceiling for other U.S. producers.

DuPont's market dominance was scrutinized in a Federal Trade Commission investigation. In 1978, DuPont was accused by the FTC of attempting to monopolize TiO_2 production, but the case was subsequently dismissed in October 1980. This finding makes it likely that DuPont will continue to dominate U.S. production and exert a strong influence on TiO_2 pricing for the next several years.

10.1.4 Economic Outlook

The future profitability of TiO_2 manufacture will depend on maintaining strong physical volume, adequate profit margins, and moderated increases in manufacturing costs.

10.1.4.1 Revenue

Total revenue is the product of the quantity sold and unit price. Though these two variables are discussed separately below, it should be recognized that they are interrelated.

10.1.4.1.1 Quantity

Sales volume of titanium dioxide, in general, reflects the overall condition of the U.S. economy. End products of TiO_2 are marketed in major sectors of the economy (e.g., construction and housing starts). The trend in volume has shown little growth over recent years (1972 to 1977) while price has increased considerably (see Graph 10-1). Long-term demand growth is expected to parallel that of the economy as a whole. That is, physical volume will increase with real GNP. The use of TiO_2 in some sectors, such as plastics, is expected to increase substantially. Most estimates anticipate an annual growth rate of approximately three percent.

10.1.4.1.2 Price

The price of TiO_2 pigments depends on the type of crystal (rutile or anatase), the grade, and the volume and form of the shipment. Minimum orders of about 20 tons are required to receive list base prices. Most shipments are made in dry form (e.g., 50 lb bags) but there are increasing amounts of shipments in the wet slurry form. Purchasers receive discounts for this form of shipment which now represents about 20 percent of volume. (This form of shipment can also reduce the quantity of water effluents at the plant.)

During the 1960's TiO_2 prices were relatively constant. From 1970 to 1972, weak demand and what industry sources describe as a "price war" caused prices to fall 11 percent below the 1968 average unit value of $511. In 1973 and 1974 demand increased markedly and, with supply unable to meet demand, prices rose six percent in 1973 and 33 percent in 1974. In 1975, the recession caused demand to fall significantly as volume dropped 23 percent. Prices, however, continued to rise as manufacturers experienced large increases in manufacturing costs (especially energy and pollution control). Overall, from 1972 to 1977, prices increased 81 percent while volume decreased one percent (see Table 10-1 and Graph 10-1).

Prices remained near 1977 levels until June of 1978 when producers raised prices 2.5 cents per pound ($50 per ton) and started to remove discounts from list prices (which were near two cents per pound). Price competition through discounting is not uncommon. Because of varying discounts it is often difficult to find the "real" price of the product. By the end of 1978, the new prices were "holding up well" i.e., there was little discounting. The list prices were: 51 cents per pound ($1,020/ton) for rutile and 46 cents per pound ($920/ton) for paper grade anatase.

10.1.4.2 Manufacturing Costs

Until recently, the chloride process for the manufacture of titanium dioxide was suitable only for use with rutile, a rare (and consequently expensive) compound. New technological advances may have ameliorated this raw material problem. According to industry sources, Quebec Iron and Titanium Company plans to build a complex in South Africa which will convert ilmenite ore into titanium slag (85 percent TiO_2). This slag will be suitable for use in sulfate plants. The company presently operates a similar plant in Sorel, Quebec which produces a 71 percent TiO_2 slag. As producers switch to these higher purity ores, it is possible that pollution control costs (quoted as high as $140 per ton of pigment) will be reduced.

DuPont, the leading manufacturer of titanium dioxide, produces TiO_2 by the chloride-ilmenite process, using ilemnite or ilmenite/rutile mixtures. Both of these improvements should begin to solve the raw materials problems as well as help to restrain prices and strengthen the industry.

Energy costs and availability will also play an important role in future TiO_2 manufacturing costs. Utilities now represent approximately 10 percent of manufacturing costs. With energy rising faster than most other input costs, manufacturing cost increases will continue to be tied to energy costs. Coke and chlorine prices will also be affected by rapidly escalating energy costs.

Manufacturing costs for TiO_2 are subject to technological advances and other producers may follow DuPont in shutting down sulfate plants and building more efficient new chloride plants. For example, SCM has said that its expansions are likely to be in additional chloride capacity (SCM Annual Report, 1977). There are now hundreds of patents worldwide covering various stages of TiO_2 manufacture and processing of ores. As these processes continue to improve and manufacturers apply more of them in their plants, manufacturing cost increases are likely to be moderated.

There are difficulties with chloride technology however, and some producers may not consider the available technologies competitive. Further research and development (or access to DuPont chlcride-ilmenite process technology) may aid in reducing manufacturing costs.

10.1.5 Characterization Summary

With manufacturing costs increasing and competitive pressure causing resistance to price increases, it will be difficult for all producers to remain profitable. One industry source has said that, except for DuPont, all U.S. manufacturers probably operated marginally or at a loss between 1975 and mid-1978. There are several factors which will influence profits in the long run. On the positive side:

- Titanium dioxide is unique in that its opacity far exceeds that of substitutes
- New ores, new technologies, and perhaps widespread use of DuPont's technology may dampen cost increases and make U.S. TiO_2 more competitive
- Capacity utilization should be adequate if demand does not falter and if some of the older plants are shut-down

However, there are several potential problems:

- Pigment demand may fall significantly if the U.S. economy experiences another recession
- DuPont's new plant (DeLisle) has added significantly to industry capacity, other producers plan to add capacity, and there is no guarantee that older plants will shut down
- Foreign competition will continue to threaten U.S. producers

Under these circumstances there is some uncertainty as to the future economic condition of the industry.

On a worldwide scale, (non-Communist) demand has increased and capacity additions have slowed. This resulted in several successful price increases in 1978. Rising demand in Japan and western Europe will reduce their propensity to export to the U.S. Thus the U.S. market should see a growth in volume of 3.0 to 3.5 percent per year and prices should be adequate for most producers.

10.2 IMPACT ANALYSIS

This section examines the potential economic impacts of requiring the titanium dioxide subcategory to comply with BAT/PSES limitations. The technical contractor has estimated the costs of compliance with BAT/PSES effluent limitations. These costs are used to make an assessment of economic impacts on the titanium dioxide subcategory.

As discussed in the characterization section, titanium dioxide is produced by the sulfate, chloride, or chloride-ilmenite process. Plants using the chloride or chloride-ilmenite process will incur no additional effluent control costs for compliance with BAT limitations:

1) For chloride process plants, BAT limitations are based on BPT. BPT equipment is already in place and operating for all chloride process titanium dioxide plants.

2) All chloride-ilmenite process plants are currently achieving removal levels equivalent to BAT standards and therefore will incur no additional effluent control costs.

Thus, the analysis of economic impacts for the titanium dioxide subcategory is confined to the impacts of BAT/PSES costs on sulfate process plants.

There are four titanium dioxide plants using the sulfate process, as summarized below:

1) One plant has BPT equipment (required to meet BAT limitations) installed and operating. This plant will incur no incremental effluent control costs.

2) A second plant is ocean-dumping part of its waste stream and discharging the remaining waste to a POTW. This plant may incur incremental costs for compliance with PSES regulations.

3) A third plant does not have land-based BPT equipment in place and therefore will incur incremental effluent control costs for compliance with BAT regulations.

4) A fourth plant has BPT equipment only partially installed. The equipment is not functioning adequately to meet BAT limitations. Therefore, this plant will incur incremental effluent control costs.

10.2.1 Pollution Control Technology and Costs

Because the chloride and sulfate processes used to manufacture titanium dioxide are inherently different and produce dissimilar waste streams, the technical contractor has developed effluent control costs separately for each process.

10.2.1.1 Sulfate Process

Two steps in the sulfate manufacturing process, filtration and washing of the precipitated product, result in two distinct wastewater streams of high and low acidity, respectively. The strong acid stream contains up to 30 percent sulfuric acid, dissolved iron, and heavy metal salts. The weak acid stream contains approximately two percent H_2SO_4 and some heavy metal sulfate salts. Other significant wastewater sources are contact cooling water, scrubber waste, and waste from final product preparation.

Achieving BAT/PSES removal levels (which are equivalent to BPT in this subcategory) will require three steps:

- Limestone precipitation of heavy metals with subsequent clarification
- Aeration of effluent from precipitation step
- Lime precipitation for settling of remaining metals.

There are three sulfate process model plants, with production rates of 35,000, 52,500 and 82,000 tons per year. The plants are designed for continuous operation, 350 days per year.

Sulfate process plants will not require iron removal (as previously proposed by EPA) in order to meet BAT/PSES limitations. Pollution control cost estimates exclusive of iron removal were developed on the basis of 1979 treatment cost estimates from the technical contractor with and without iron removal.

Table 10-6a shows the BAT/PSES cost estimates with and without iron removal for the three sulfate process model plants. It should be noted that one plant, corresponding to model size three, is currently ocean dumping a portion of its waste stream (and will be allowed to continue ocean dumping through at least 1989) and discharging the remainder of its waste stream to a POTW. This plant may require additional pretreatment for the portion of its effluent being discharged to a POTW. Technical contractor estimates indicate that the plant's cost for additional pretreatment would be approximately 25 percent of the costs of a total land-based pretreatment system. Therefore, this plant's costs are estimated as 25 percent of the corresponding model plant's costs.

Sales of by-product gypsum (generated by the waste treatment process) may help defray part of these effluent treatment operating costs. The technical contractor has estimated that sales of by-product gypsum (generated by effluent treatment equipment) could reduce BAT/PSES costs for sulfate process titanium dioxide (TiO_2) plants by $22 per ton of TiO_2 production. However, it is possible that the total volume of gypsum by-product may not be sold (or could be sold only at reduced prices).

Table 10-6b shows the effect of three gypsum credit scenarios on BAT/PSES costs for each sulfate process model plant. The three gypsum credit scenarios are:

1) Sulfate plants receive no gypsum by-product sales credit.
2) Sulfate plants receive only half of the $22 (per ton of TiO_2) reduction in costs as a result of unsuccessful sales and/or gypsum price reductions required to sell the by-product.
3) Sulfate plants receive the full $22 (per ton of TiO_2) reduction in effluent treatment costs with successful sale of their total gypsum production.

(Note that the required price increase and maximum potential profitability decline are calculated assuming no, half, and full gypsum credits for each model plant to define the possible range of price and profitability impacts.)

Titanium dioxide manufacturing cost estimates for sulfate process plants are $985.60, $929.40, and $903.40 per ton for the small, medium, and

TABLE 10-6a

POLLUTION CONTROL COSTS

Chemical: Titanium Dioxide - Sulfate Process

MODEL PLANT PRODUCTION (tons/year)	BAT/PSES COSTS INCLUDING IRON REMOVAL		IRON REMOVAL COSTS AS PERCENT OF TOTAL COSTS*		BAT/PSES COSTS EXCLUDING IRON REMOVAL	
	Capital	Operating	Capital	Operating	Capital	Operating
35,000	$5,755,225	$3,024,979	53.56%	17.74%	$2,672,727	$2,488,348
52,500	$7,608,705	$4,321,132	53.88%	16.25%	$3,509,135	$3,618,948
82,000	$2,633,639*	$1,525,123*	53.45%	12.94%	$1,225,959*	$1,327,772*

*This plant may require additional pretreatment for a portion of its waste stream. These additional pretreatment costs are estimated as 25 percent of the costs of a total pretreatment system for the corresponding model plant.

SOURCE: Technical Contractor

Note:
- o All costs are in mid-1978 dollars.
- o Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-6b

EFFECT OF GYPSUM CREDIT ON SULFATE PROCESS
BAT/PSES COSTS

MODEL PLANT PRODUCTION (tons/year)	CAPITAL COST	OPERATING COST		
		NO GYPSUM CREDIT	HALF GYPSUM CREDIT	FULL GYPSUM CREDIT
35,000	$2,672,727	$2,488,348	$2,102,699	$1,717,050
52,500	$3,509,135	$3,618,948	$3,040,469	$2,461,990
82,000*	$1,225,959	$1,327,772	$1,101,898	$ 876,024

*The plant corresponding to this model size may require additional pretreatment for a portion of its waste stream. These additional costs are estimated as 25 percent of the costs of a total pretreatment system for the corresponding model plant. The full gypsum credit is estimated as $5.50 (25 percent of $22) per ton of TiO_2.

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

large model plants excluding the costs of pollution control (See Table 10-3). Table 10-7 summarizes titanium dioxide sulfate process model plant financial parameters.

The total investment and annualized control costs for sulfate process plants are summarized in Table 10-8. Currently, one of the four plants (corresponding to model size 2) has BPT effluent control equipment installed and operating and will require no additional costs for compliance with BAT/PSES limitations. As indicated in the table, the additional annualized subcategory costs required for compliance with BAT/PSES limitations are estimated as approximately $7.9 million assuming no gypsum credit. A full gypsum credit would reduce these costs by about $2 million per year to $5.9 million annually. Also note that one of the Size 1 plants currently has partial compliance equipment in place. This is not reflected in the analysis, which therefore overstates the incremental costs for this plant and total subcategory compliance costs.

10.2.1.2 Chloride Process

For chloride process plants, BAT limitations are based on BPT, already in place and operating for all six chloride process plants. BPT removal includes three steps:

- Equalization of effluent
- Lime precipitation of effluent
- Settling or clarification before discharge

The technical contractor estimated BPT costs for three chloride process model plant sizes, producing 18,500, 28,000, and 50,000 tons per year. Table 10-9 shows these costs. As noted above, since BAT is based on BPT (already in place and operating for all chloride process plants), chloride process titanium dioxide plants will incur no incremental costs for compliance with BAT limitations.

10.2.1.3 Chloride-Ilmenite Process

As noted above, all three chloride-ilmenite process plants are currently achieving removal levels equivalent to BAT limitations and, therefore, will incur no incremental effluent control costs.

10.2.2 Model Plant Analysis

This section outines the results of the model plant analysis used to determine industry impacts. Four indicators which help define the magnitude of the control cost impacts are presented:

- Price Rise - the calculation of the price increase required to fully recover the increased pollution control costs.
- Profitability Decline - the maximum decline in profitability that would result if no price increase were possible.
- Price Elasticity of Demand - a subjective estimate based on information developed in the characterization section; it suggests the degree to which the price can be raised and the probable profitability decline.
- The Capital Ratio - the ratio of pollution control capital costs to fixed investment in plant and equipment.

The EPA considers the price rise, profitability decline, and price elasticity of demand useful in providing an initial indication of plant closure probability. In this way potentially "high impact" plants can be screened for additional analysis.

The impact analysis is not performed for chloride or chloride-ilmenite process titanium dioxide plants; these plants are already in compliance with BAT limitations. Therefore, the model plant analysis results are presented only for the sulfate process.

10.2.2.1 Price Rise Analysis

The price rise analysis assumes full pass-through of all pollution control costs. Clearly, the price increases necessary for sulfate

TABLE 10-7 : MANUFACTURING COSTS

Chemical: Titanium Dioxide - Sulfate Process

Model Plant Production (tons/year)	Investment in Plant and Equipment	Manufacturing Costs Per Ton
35,000	$84,200,000	$985.60
52,500	111,800,000	929.40
82,000	153,000,000	903.40

Note: All costs are in mid-1978 dollars.

TABLE 10-8

SUBCATEGORY COMPLIANCE COSTS

Chemical: Titanium Dioxide - Sulfate Process

BAT/PSES*

MODEL PLANT PRODUCTION (tons/year)	ESTIMATED ANNUAL PRODUCTION BY AFFECTED PLANTS (tons)	INVESTMENT COSTS	ANNUALIZED COST ($/year)		
			NO GYPSUM CREDIT	HALF GYPSUM CREDIT	FULL GYPSUM CREDIT
35,000	73,720	$5,345,454	$6,457,872	$5,646,952	$4,836,032
52,500	0	NA	NA	NA	NA
82,000	76,000**	$1,225,959	$1,475,920	$1,266,920	$1,057,920
TOTAL	149,720	$6,571,413	$7,933,792	$6,913,872	$5,893,952

* For this subcategory, BAT and PSES costs are equivalent.

**The plant corresponding to this model size may require additional pretreatment for a portion of its waste stream. These additional costs are estimated as 25 percent of the costs of a total pretreatment system. The full gypsum credit is estimated as $5.50 (25 percent of $22) per ton of TiO_2.

NA: Not applicable — no plants incurring costs.

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-9: POLLUTION CONTROL COSTS

Chemical: Titanium Dioxide - Chloride Process

Model Plant Production (tons/year)	BPT/PSES		BAT	
	Capital Investment	Annual Operating Cost	Capital Investment	Annual Operating Cost
18,500	$ 800,111	$409,714	For this subcategory, BAT is the same as BPT. There are no incremental costs over BPT for compliance with BAT regulations.	
28,000	1,003,274	555,626		
50,000	1,551,420	977,284		

SOURCE: Technical Contractor

Note: All costs are in mid-1978 dollars.

process plants to pass through BAT/PSES costs will depend on the magnitude of the gypsum by-product credit obtainable. Price increases were calculated assuming no, half, and full gypsum credit. For the 35,000 ton per year (TPY) model plant, the required price increase ranges from 7.13 percent (with full gypsum credit) to 9.52 percent (with no gypsum credit). The 52,500 TPY model plant would require price increases between seven and nine percent and the 82,000 TPY model would require a one to two percent price rise. Table 10-10 summarizes these required price increases for sulfate process titanium dioxide manufacturers.

10.2.2.2 Profitability Analysis

The profitability analysis calculates the decline in the return on investment (ROI) and the internal rate of return (IRR) when no price pass-through is assumed.

Because the by-product gypsum generated by effluent treatment equipment has a marketable value, the actual profitability decline due to pollution control compliance will depend on the credit received from by-product gypsum sales. Tables 10-11a, 10-11b, and 10-11c present the model plant profitability impacts of effluent control costs under three gypsum credit scenarios.

1) Sulfate plants receive no gypsum by-product sales credit.
2) Sulfate plants receive only half of the $22 per ton of TiO_2 reduction in costs as a result of unsuccessful sales and/or gypsum price reductions required to sell the by-product.
3) Sulfate plants receive the full $22 per ton of TiO_2 production (as estimated by the technical contractor) reduction in effluent treatment costs with successful sale of their total gypsum production.

As shown in the tables, application of BAT/PSES costs to the largest sulfate model plant reduced the IRR by less than one percentage point (or by less than seven percent from the base case) in all scenarios. However, for the small and medium model plant sizes, the IRR declined by over one percentage point in all gypsum credit scenarios. With no

TABLE 10-10

PERCENTAGE PRICE RISE

Chemical: Titanium Dioxide - Sulfate Process

Price: $920/ton

MODEL PLANT PRODUCTION (tons/year)	BAT/PSES*		
	WITH NO GYPSUM CREDIT	WITH HALF GYPSUM CREDIT	WITH FULL GYPSUM CREDIT
35,000	9.52%	8.33%	7.13%
52,000	9.06	7.87	6.67
82,000	2.11	1.81	1.51

*For this subcategory, BAT and PSES costs are equivalent.

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-11a

PROFITABILITY CHANGE

Chemical: Titanium Dioxide - Sulfate Process

Level: BAT/PSES

(no gypsum credit)

MODEL PLANT PRODUCTION (tons/year)	RETURN ON INVESTMENT			INTERNAL RATE OF RETURN		
	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)
35,000	8.40%	4.82%	-3.58 (-42.62%)	7.53%	2.89%	-4.64 (-61.62%)
52,000	10.56	7.09	-3.47 (-32.86)	9.84	6.11	-3.73 (-37.91)
82,000	11.38	10.84	-0.54 (-4.75)	10.93	10.18	-0.75 (-6.86)

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-11b

PROFITABILITY CHANGE

Chemical: Titanium Dioxide - Sulfate Process

Level: BAT/PSES

(half gypsum credit)

MODEL PLANT PRODUCTION (tons/year)	RETURN ON INVESTMENT			INTERNAL RATE OF RETURN		
	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)
35,000	8.40%	5.33%	-3.07 (-36.55%)	7.53%	3.70%	-3.83 (-50.86%)
52,000	10.56	7.67	-2.89 (-27.37)	9.84	6.78	-3.06 (-31.10)
82,000	11.38	10.92	-0.46 (-4.04)	10.93	10.30	-0.63 (-5.76)

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-11c

PROFITABILITY CHANGE

Chemical: Titanium Dioxide - Sulfate Process

Level: BAT/PSES

(full gypsum credit)

MODEL PLANT PRODUCTION (tons/year)	RETURN ON INVESTMENT			INTERNAL RATE OF RETURN		
	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)	BASE CASE	WITH CONTROL EQUIPMENT	PERCENTAGE POINT CHANGE (PERCENT CHANGE)
35,000	8.40%	5.85%	-2.77 (-32.98%)	7.53%	4.47%	-3.06 (-40.64%)
52,000	10.56	8.25	-2.31 (-21.88)	9.84	7.40	-2.44 (-24.80)
82,000	11.38	11.01	-0.37 (-3.25)	10.93	10.42	-0.51 (-4.67)

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

gypsum credit, the small model plant incurs a 4.6 percentage point decline in profitability (representing over 61 percent of baseline profitability). Even with the full gypsum credit, the small model plant's IRR declines by over three percentage points (over 40 percent from the base case). The medium model plant experiences a 3.7 percentage point decline (about 38 percent of baseline profitability) with no gypsum credit and a 2.4 percentage point decline (about 25 percent of baseline profitability) with the full gypsum credit.

10.2.2.3 Price Elasticity of Demand

Titanium dioxide is a unique white pigment, and therefore has no real substitute. This lack of substitutes implies that the demand for titanium dioxide is relatively price inelastic. However, due to rigorous competition between domestic and foreign producers for U.S. market share, U.S. prices are constrained by import prices, and demand facing the U.S. industry is slightly elastic. (See Sections 10.1.1, Demand and 10.1.3, Competition, for a complete analysis.) Since sulfate process production is the only segment of the titanium dioxide subcategory incurring effluent control costs, and TiO_2 produced by either the chloride or chloride-ilmenite process is a perfect substitute for sulfate process TiO_2, demand for sulfate process producers' titanium dioxide is highly elastic.

10.2.2.4 Capital Analysis

Raising capital for the pollution control investment required by sulfate process BAT/PSES limitations in an amount less than or approximately three percent (see Table 10-12) of fixed capital investment should not pose significant problems for sulfate process titanium dioxide producers. All of the firms involved probably have sufficient capital at the corporate level. Thus the capital investment hurdle probably will not prevent the installation of pollution control equipment. The critical issue, however, is whether sufficient price increases could be passed through to justify the investment from a long run capital budgeting point of view.

10.2.2.5 Closure Analysis

Table 10-13 illustrates that for BAT/PSES costs, the small and medium sulfate model plants are likely closure candidates according to the EPA's suggested closure criteria. Since the price of titanium dioxide is severely constrained by import prices and by the domestic price set by the lowest cost producers, demand facing producers in the sulfate subcategory is highly elastic. Therefore, producers may suffer the full profitability decline. The magnitude of this decline is likely to cause producers to consider shutdown. Section 10.2.3 discusses the probability and impact of actual plant closures in more detail.

10.2.3 Industry Impacts

In this section, the model plant results described above are used to determine the probable industry price rise, profitability decline, and resulting impacts on sulfate process titanium dioxide manufacturers.

10.2.3.1 Price and Profitability Impacts

The model plant analysis results indicate that plants corresponding to the small or medium model size will experience severe impacts from BAT/PSES costs. Required price increases (even with a full gypsum credit) are substantially above one percent and two factors may significantly constrain price increases. First is competition from chloride and chloride-ilmenite process producers, particularly from DuPont, a firm which is in a good position to avoid large price increases, and whose market share (55 percent of titanium dioxide capacity) may be large enough to influence the pricing decisions of other producers. DuPont is the single chloride-ilmenite process titanium dioxide producer, holding sole rights to the unique comparatively low-cost process. Further, DuPont's chloride-ilmenite plants will incur no additional effluent control costs since they are capable of achieving removal levels equivalent to BAT limitations via the relatively inexpensive deep-well injection process at two of its plants and via ocean dumping

TABLE 10-12

POLLUTION CONTROL CAPITAL COSTS AS A PERCENTAGE OF FIXED INVESTMENT

Chemical: Titanium Dioxide - Sulfate Process

	Model Plant Production (tons/year)		
Level of Removal	35,000	52,500	82,000
BAT/PSES*	3.17%	3.14%	0.08%

*For this subcategory, BAT and PSES costs are equivalent.

Note: Costs and resulting impacts are overstated for one of the two plants corresponding to model Size 1. See Sections 10.2.1.1 and 10.2.3.2.

TABLE 10-13

IMPACT SUMMARY

Chemical: Titanium Dioxide - Sulfate Process

	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PROFITABILITY DECLINE	CLOSURES
CLOSURE CRITERIA DESCRIBED IN METHODOLOGY SECTION	Medium or High	Greater Than 1%	Greater Than 1 Percentage Point or Greater Than 10 Percent of Baseline Profitability	Predicted If all Criteria Met

MODEL PLANT RESULTS

REMOVAL LEVEL	PLANT PRODUCTION (ton/year)	PRICE ELASTICITY	MAXIMUM PRICE RISE	MAXIMUM PERCENTAGE POINT PROFITABILITY DECLINE (% DECLINE)	CLOSURES
BAT/PSES*	35,000	High	9.52%	4.64 (61.62%)	May result in the small or medium size categories
	52,500		9.06	3.73 (37.91%)	
	82,000		2.11	0.75 (6.86%)	

*For this subcategory, BAT and PSES costs are equivalent.

at the third plant. Chloride process producers will not incur any additional effluent control costs at this time.

Second, foreign titanium dioxide is very price-competitive and occasionally undersells domestic products. If foreign producers do not face similar cost increases, domestic producers will have to moderate their price pass-through to retain their market share.

The high pollution control costs will put sulfate producers at a significant cost disadvantage relative to imports and the other domestic production processes. Domestic sulfate process producers may be able to completely pass through cost increases over a period of years. They will, however, face depressed or negative profitability during the interim time period. During 1978 some sulfate producers went from a loss situation to one of positive profits. Although this was partially due to volume increases, a \$0.05 price increase from \$0.41 to \$0.46 per pound was a major factor. Pollution control costs of \$0.04 per pound (which are indicated by this analysis) would significantly reduce their profitability.

An example of the effects of pollution control costs on competition is illustrated by the American Cyanamid Corporation. The corporation installed a \$17 million treatment facility at their Savannah, Georgia plant in response to the 1977 Effluent Limitations Guidelines. When these regulations were remanded by the courts, American Cyanamid was left in the position of having installed an expensive process and equipment, while some of its competitors had not. In order to remain competitive, American Cyanamid entered into a consent agreement with the State of Georgia, under which the plant bypasses a large segment of the treatment process and discharges directly into the surface waters following neutralization. SCM also had a multi-million dollar pollution control system installed in its Baltimore plant. However, the system is undersized and successful continuous operation of the pollution control system has not been achieved.

Given that the probability of pass-through is low for sulfate process plants, these producers are likely to suffer the full profitability decline. Depending on the gypsum credit obtainable, small plants will incur profitability declines of 3.1 to 4.6 percentage points (40.64 percent to 61.62 percent of baseline profitability) and medium plants will incur declines of 2.4 to 3.7 percentage points (24.80 percent to 37.91 percent of baseline profitability). The implications of these profitability declines for plant closure decisions are discussed in Section 10.2.3.2.

10.2.3.2 Other Impacts and Conclusion

As noted above, there are four sulfate process plants. Two plants correspond to the small model size. The only plant corresponding to model size 2 already has BPT in place and operating and, therefore, will incur no additional effluent control costs for compliance with BAT/PSES limitations. The model plant analysis indicated profitability declines of less than one percentage point (and less than 10 percent of baseline profitability) for the large model plant size. Therefore, the single plant corresponding to this size category is not likely to suffer severe impacts from BAT/PSES costs.

Given the large price and profitability impacts for small sulfate plants, it is possible that both small plants would close. However, while the quantitative indicators do suggest a high probability of closures, the actual circumstances of these plants make closures appear highly unlikely. As noted previously, on plant has already made a partial investment in treatment equipment. The analysis does not reflect this investment, and therefore overstates the price and profitability impacts for the plant. In addition:

- The final regulation incorporates specific changes requested by this producer.
- Company spokesman have publicly announced that they plan to continue production, and foresee a long-term market for the anatase grade produced by the sulfate process (Chemical Marketing Reporter, December 24, 1979).

The other plant has recently signed a court agreement to meet limitations equal to those set forth in the final regulation and has agreed to install wastewater treatment controls and continue production in compliance with the regulation. Accordingly, continued operation of that plant appears likely.

In summary, although the quantitative indicators show significant negative impacts, the actual circumstances of these plants makes closures very unlikely.

APPENDIX A

EXPLANATION OF THE PRICE RISE CALCULATIONS

The basic model plant price rise calculation is:

$$\begin{array}{l}\text{Unit price increase needed}\\ \text{to recover all pollution}\\ \text{control costs}\end{array} = \left(\begin{array}{c}\text{pollution control}\\ \text{annual operating}\\ \text{costs}\end{array} + \begin{array}{c}\text{pollution control}\\ \text{annualized capital}\\ \text{costs}\end{array}\right) \div \begin{array}{c}\text{annual}\\ \text{production}\end{array}$$

Of the three terms on the right side of the equation, the annual operating costs* and annual plant production are given by the technical contractor. What must be calculated is the annualized capital cost -- i.e., the annual cash return required to recover all capital investment costs plus a specified return on investment. This annualized capital cost is estimated by use of a capital recovery factor, which is multiplied by initial investment to yield the annual capital cost which must be recovered. The remainder of this section will show how the capital recovery factor is derived.

The calculation of the capital recovery factor is based on the following economic assumptions:

- Capital is composed of 65 percent equity and 35 percent debt.
- The required return on equity is 15 percent.
- The interest rate on debt is 12 percent before tax (i.e., 2 percentage points above an assumed 10 pecent prime rate).

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*In calculating the annual operating costs required for RCRA-ISS compliance in the affected subcategories, the annual closure fund payment is divided by (1 - tax rate), or 0.53, to reflect the fact that this payment is a non-tax deductible expense, unlike other operating costs. See Section 3.2.3 of the Methodology Description for futher discussion.

- Marginal income tax rate of 47 percent. This is calculated as follows:

  (1) $TS + (1-TS) \times TF = TR$
  where:
  TR is the marginal income tax rate
  TS is the marginal state income tax rate (.02)
  TF is the federal marginal income tax rate (.46)

- Depreciation is 15 years, straight-line[1]

- Construction period is zero years, with no interest during construction

The first step is to estimate the after-tax cost of capital. This is the weighted average of the cost of equity and debt, or:

(2) 65 percent equity x 15 percent cost of equity = 9.75 percent
35 percent debt x (12 percent x (1-TR))[2] = 2.23 percent
11.98 percent

Given the weighted cost of capital, it is then possible to estimate the cash flow required to recover the initial investment. This is done via the following formula:

$$(3) \quad CF = \frac{i\,(1+i)^n}{(1+i)^n-1}$$

where: i = weighted cost of capital
n = number of periods
CF = cash flow

---

[1] For tax purposes pollution control equipment can be depreciated over as few as five years. This five year assumption (and 10 years for other investment) is incorporated in the cash flow calculations used to develop the return-on-investment indicators, since these calculations must reflect the actual cash returns which would be shown in an income tax return. However, in the case of the capital recovery factor, which is internal to the corporation, a longer 15 year depreciable period is used. This is because the larger period better reflects the life of the equipment, and moderates the immediate required price-rise.

[2] i.e., 35 percent times the after-tax interest rate on debt.

Substituting 11.98 percent for i and 15 years for n, the equation reduces to 0.147. In other words, every dollar of initial investment requires an annual return of $0.147 to yield an after tax return on capital of 11.98 percent.[1/]

CF, the cash flow, only shows the direct return required on capital investment. The next step is to estimate the total revenue requirement needed to recover the initial investment, including the effects of depreciation and taxes on required revenue. In order to solve for the revenue-based capital recovery factor (CRF), the calculations begin with the following formula:

$$(4)\quad (R-OC-D) \times (1-TR) = NIAT$$

where: R = revenue
OC = operating costs
D = depreciation factor
TR = marginal tax rate
NIAT = net income after taxes

Operating costs can be set equal to zero and ignored since this calculation is concerned only with returns to the capital cost portion of the investment. If depreciation, a paper expense rather than a real drain on income is added back in, equation (4) will reduce to total cash returns, or cash flow (CF):

$$(5)\quad [(R-D)\,(1-TR)] + D = CF$$

The term 1-TR equals 1-.47, or 0.53. Using this value, equation (5) becomes:

$$(6)\quad .53R - .53D + D = CF$$

or

$$(7)\quad .53R + .47D = CF$$

[1/] Another way of stating this is that the present value of $0.147 per year for 15 years is $1.00.

Solving for R, equation (7) becomes:

(8) $.53R = CF - .47D$

(9) $R = \frac{CF}{.53} - \frac{.47D}{.53}$

This equation represents the annualized cash flow and depreciation for a 15 year investment. To solve for the annual revenue requirement per dollar of investment -- i.e., the revenue-basis capital recovery factor -- the previously determined values for CF (0.147) and D (0.067) are substituted in:

(10) $R = \frac{.147}{.53} - \frac{.47(.067)}{.53}$

(11) $R = .218$

In other words, for each dollar of capital investment the firm must recover $0.218 annually in order to recover all capital costs plus the 11.98 percent return on investment.

The factor of 0.218 is used for depreciable initial investment. This factor applies to the effluent control investment costs and to the RCRA-ISS capital costs. However, a portion of the initial RCRA-ISS control costs for each model plant in the affected subcategories cannot be depreciated; that is, they are capitalized expenses. Calculation of the capital recovery factor for non-depreciable investment proceeds as above, except that no depreciation allowance is included. Therefore, instead of equation (5), the following equation is used:

(12) $R \times (1-TR) = CF$

Substituting in the known values, this becomes

(13) $R \times (1-.47) = .147$

(14) $R = .278$

Thus, the unit price rise required to recover all pollution control costs is simply (total operating costs) plus (annualized capital costs) divided by (total production). Operating costs and total production are given. Annualized capital costs are calculated by multiplying capital investment costs by the appropriate capital recovery factor, with depreciable capital expenses multiplied by .218 and non-depreciable investment multiplied by .278.

APPENDIX B

DERIVATION OF THE FINANCIAL ANALYSIS EQUATIONS

The cash flows in the internal rate of return (IRR) and net present value (NPV) calculations are discounted to reflect the fact that a dollar received in the future is less valuable than one received today. The present value of a cash flow over n time periods is:

$$NPV = \frac{CF_1}{(1+k)} + \frac{CF_2}{(1+k)^2} + \ldots \frac{CF_n}{(1+k)^n}$$

The cash flow (CF) for each period is the total revenue minus total costs for that period and can be negative or positive. The cash flows are also affected by the inflation rate. The inflation rates are assumed constant throughout the life of the plant: operating costs and chemical product prices are all assumed to inflate at 6% annually. The discount factor (k) is usually taken to be the cost of capital and reflects the opportunity cost between receiving a dollar in the present and receiving a dollar one time period in the future. In calculating the net present value the cash flows and discount rates are known and the present value is calculated from equation 7 (Table B-1). To calculate the internal rate of return the net present value (NPV) is set equal to zero and equation 6 (Table B-1) is solved yielding a value for r.[1] Return on investment (ROI) is the ratio of total investment to cash flow in a given year.

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[1] If the cash flows are not well behaved, it is possible to have two values of "r" that satisfy the equation. See J.F. Weston and E.F. Brigham; Managerial Finance, fifth ed.; Dryden Press; Hinedale, Illinois, 1975, (p. 296).

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The equations and assumptions used to derive IRR, NPV, and ROI are presented in Table B-1.

TABLE B-1

IRR, NPV, AND ROI EQUATIONS

(1) **Tax Rate and Credits**

$TR = .47$

$ITC_f = .08 \times FI$ (where the investment tax credit for fixed investment in plant and equipment is 8%, taken in the third year)

$ITCpc = .1 \times PCI$ (where the investment tax credit for pollution control equipment is 10%, taken the year after the investment is made)

(2) **Taxable Income**

$$TI_t = REV_t - OP_t - DEP_t$$

(3) **Depreciation***

10 year double-declining balance/straight line for fixed investment
5 year straight line for pollution control investment

(4) **Tax Liability**

$$TL = TR \times TI$$

(5) **Cash Flow**

$$CF = (TI - TL)_t + DEP_t + ITC_{total} - FI^{**}$$

(6) **Internal Rate of Return** (solve for r)

$$0 = \sum_{t=1}^{27} CF_t \left(\frac{1}{1 + r}\right)^t - FI + PCI$$

(7) **Net Present Value**

$$NPV = \sum_{t=1}^{27} CF_t \left(\frac{1}{1+k}\right)^t$$

---

* See Footnote 1, page apx-2.

**Cash flow after pollution control would be calculated by also subtracting PCI in this equation.

TABLE B-1 (Continued)

IRR, NPV, AND ROI EQUATIONS

(8) Return on Investment

$ROI_t = CF_t \div \text{Total Investment}$ (for this analysis cash flow was always calculated for the fourth year; i.e. t=4)

(9) Inflation Rate

Prices, operating costs, and capital costs increase at the rate of 6 percent annually.

Variable Names and Values

TR = Marginal income tax rate (0.47)

ITCpc= Investment tax credit for pollution control equipment (.10 x PCI)

ITC_f = Investment tax credit for fixed plant and equipment (.08 x FI)

$ITC_{total} = ITCpc + ITCf$

FI = Fixed investment

PCI = Pollution control investment

TI = Taxable income

REV = Revenues

OP = Operating Costs

DEP = Depreciation

TL = Tax liability

CF = Cash flow

k = Discount factor or cost of capital (11.98 percent)

t = Time period (year)

r = Internal Rate of Return

APPENDIX C

THE MANUFACTURING COST ESTIMATES: SOURCES, USES, AND LIMITATIONS

The manufacturing cost tables presented in the characterization section for each subcategory are process engineering estimates. These costs are not necessarily based on the cost experience of an actual plant in the industry. In fact, costs may be under- or overstated for several reasons.

For example, the raw materials variable costs assume that materials and power are purchased at published list price. For a given plant, material prices may actually be lower due to the existence of long term contracts or captive supply sources. Materials and utility costs vary geographically: chemicals are generally more expensive in the West; natural gas is often less expensive on the Gulf Coast; electricity rates vary widely depending on the local utilities' fuel mix.

The semi-variable and fixed cost estimates were calculated using accepted process-economic algorithms to allocate overhead expenses. Labor costs include operating labor and labor overhead. Operating labor cost estimates were based on labor requirements and an average wage. Labor overhead was taken as a percentage of labor costs ranging from 40 to 60 percent, depending on the process. Maintenance and plant overhead were estimated as a portion of either fixed investment or labor costs depending upon the process. Depreciation was calculated as 10 percent of fixed investment. Since the fixed investment estimate is in 1978 dollars, and therefore represents the replacement cost for the plant, these overhead costs probably overstate the manufacturing costs for plants built before the rapid capital inflation of the early 1970's. Taxes and insurance were calculated as 1.5 or two percent of fixed investment.

While the uncertainty inherent in the engineering cost estimates is substantial, they are highly useful in this analysis for a number of reasons. First, variable costs estimates can indicate which chemical processes are presently vulnerable to rising energy costs or shortages of key materials which will tend to rapidly inflate the manufacturing costs. Second, while the semi-variable and fixed costs estimates are subject to a wide margin of error, they still provide an indication of scale economies. This facilitates the analysis of differential impacts within subcategories.

The cost estimates were used to calculate model plant profitability. However, impacts were evaluated not on the basis of the absolute levels of profitability, but rather according to the decline in profitability which resulted from the pollution control costs. Since the magnitude of profitability decline does not vary with the absolute profitability level (see Appendix D), the manufacturing costs as estimated serve the purpose of the analysis.

APPENDIX D

SENSITIVITY OF THE PROFITABILITY ANALYSIS TO THE FINANCIAL DATA

1. INTRODUCTION

One of the tools employed to measure the economic impact of pollution control costs on the model plants is the discounted cash flow (DCF) analysis, from which the internal rate of return (IRR) is derived. The internal rate of return is computed for each model plant before and after pollution control costs are incurred. The resulting model plant profitability decline is analyzed (along with other measures developed for the model and industry specific information) to determine:

- **Differential impacts among plants in a subcategory**
- **Probability of plant closures**
- **Effects on industry structure and growth**

That is, it is necessary to determine how changes in the financial parameters used would alter the results of the profitability analysis and, therefore, the conclusions made in the impact assessment.

2. HOW THE PROFITABILITY ANALYSIS IS USED

The profitability analysis is designed as a simulation model. The financial parameters are estimated as accurately as possible in order to generate an internal rate of return that reflects the actual industry profitability. As in any simulation model, the results are subject to the judgement of the modelers. The model financial parameters and resulting profitability figures were refined by intensive analysis of the subcategory and contacts with the industry.

The magnitude of the modeled profitability decline is evaluated to assess the probability of closure in the actual plants represented by the models used in the analysis. One of two possible conclusions is drawn depending on the magnitude of the profitability decline:

- The profitability decline will not result in the model plant becoming unprofitable if the magnitude of the decline is small in relation to the baseline profitability level.

- The profiability decline may result in the model plant profitability becoming negative or nearly so if the magnitude of the decline is large in relation to the baseline profitability level. In this case, the probability of plant closure resulting from the profitability decline is assessed.

Implicit is the assumption that the actual magnitude of the profitability change does not vary significantly with baseline profitability levels. The analysis assumes that over a reasonable distribution of profitability levels around the base level, the magnitude of the profitability decline resulting from pollution control costs is approximately the same. For example, if a model plant has 25 percent baseline profitability which declines by two percentage points to 23 percent with pollution control, it is assumed that if the same model has 20 percent baseline profitability, the plant would also incur approximately a two percentage point decline - from 20 to 18 percent - given the same pollution control costs. If this assumption is wrong, two types of errors are possible:

- High impacts may be understated by small profitability declines;
- Low impacts may be overstated by large profitability declines.

Therefore, it is important to determine whether the absolute magnitude of the profitability decline is dependent upon the absolute level of profitability, and if so, to what extent. If the size of the decline is largely determined by the baseline profitability, then the profitability analysis is of only limited value. However, if the results of the sensitivity analysis indicate that the magnitude of the profitability decline is unaffected by the baseline profitability, then the profitability analysis is a valuable tool.

3. RESULTS OF THE SENSITIVITY ANALYSIS

The computer model was used to generate IRR's given a range of different baseline profitability assumptions. IRR's were computed both without pollution control costs (the baseline profitability) and with costs.[1] The magnitude of the decline in IRR was calculated and plotted as a function of the baseline IRR. The results for two representative cases are presented in Graphs D-1 and D-2.

Graph D-1 shows how the magnitude of the profitability decline changes with baseline IRR for one chrome pigments model plant. In this case, the control costs are substantial (pollution control capital costs of $2.4 million are approximately one-third the capital cost of the manufacturing facility; total annualized costs are 5.3 percent of the selling price of the product). The impact analysis indicates that the model plant will incur a large profitability decline of about 10 percentage points. At a baseline profitability level (20 percent), the decline is larger (about 11.5 percentage points). The absolute magnitude of the decline varies within a narrow range between 10 and 11.5 percentage points over baseline profitability levels ranging from 20 to 55 percent.

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[1] The results presented in this section were obtained from the sensitivity analysis conducted for the April 1980 "Economic Analysis of Proposed Revised Effluent Guidelines and Standards for the Inorganic Chemicals Industry." The same model plant financial parameters used in the April 1980 effluent guidelines report are used in this analysis. Therefore, the sensitivity analysis results presented in the earlier report are also applicable to this analysis.

For the sodium hydrosulfite model plant, the pollution control costs are relatively small (capital costs are 1.49 percent of investment in fixed plant and equipment; total annualized costs are 1.4 percent of product price) and this is reflected in the small profitability decline. The decline ranges from .5 to 1.3 percentage points over baseline IRR levels ranging between six and 30 percent. (See Graph D-2.)

In both cases, the magnitude of the profitability decline varies within a narrow range (between one and two percentage points), implying that large profitability declines remain large and small declines remain small.

4. FURTHER DISCUSSION

Two aspects of the graphs are of further interest:

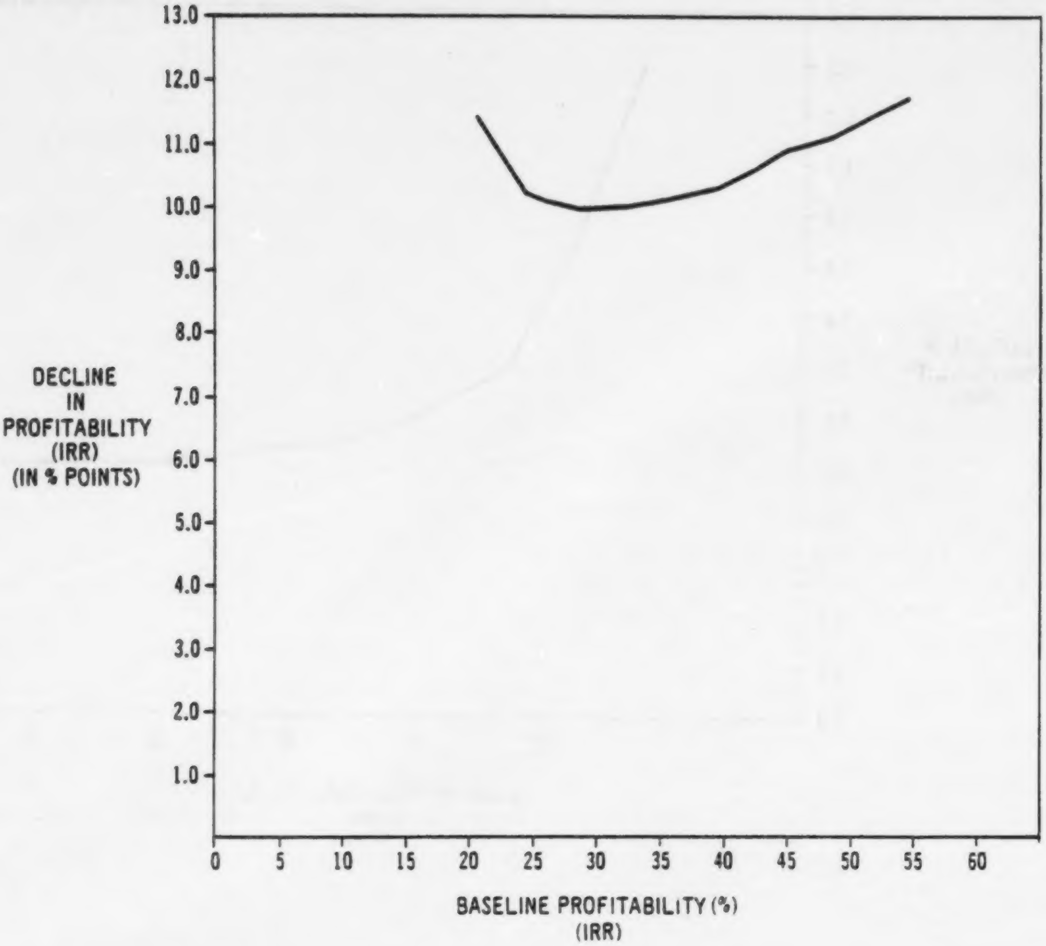
- At the lower end of the baseline profitability scale, the change in profitability begins to increase, apparently asymptotically;
- At the upper end of the baseline profitability scale, the profitability decline increases in one case and decreases in the other.

The asymptotic increase in the profitability decline at the low end of the scale is due to a simplifying assumption of the model. In actual business practice, a firm can use a portion of a loss to reduce its future tax liability. More importantly for its immediate cash position, it can "carry-back" a portion of the loss and apply it against taxes paid in profitable years. Through this provision it can receive a refund of some, or possibly all of the taxes it paid in those years.

The model, however, does not include these provisions. Therefore, while it does incorporate the effect of taxes on restraining the growth in net income, it does not show how the tax laws can act to reduce losses. This point is illustrated by Table D-1. As income increases, as from

GRAPH D-1

PROFITABILITY DECLINE V. BASELINE PROFITABILITY LARGE CHROME PIGMENTS MODEL PLANT



GRAPH D-2
PROFITABILITY DECLINE V. BASELINE PROFITABILITY SODIUM HYDROSULFITE MODEL PLANT

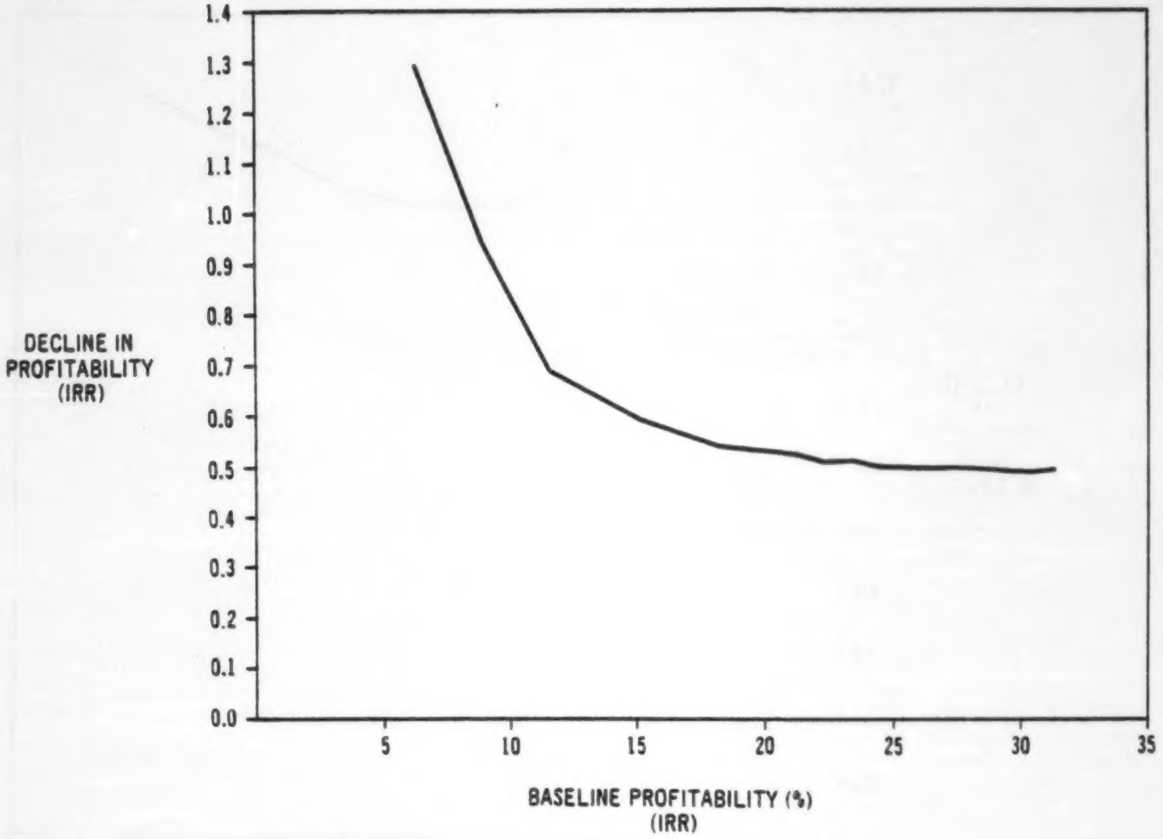


TABLE D-1

EFFECT OF SIMPLIFYING TAX ASSUMPTION ON CASH FLOW STREAM

Period	Revenues	Operating Costs	Depreciation	Tax*	Cash Flow+	Change in Cash Flow from Previous Period
1	12	8	2	1	3	
2	12	7	2	1.5	3.5	.5
3	12	8	2	1	3	- .5
4	12	9	2	.5	2.5	- .5
5	12	10	2	0	2	- .5
6	12	11	2	0	1	-1
7	12	12	2	0	0	-1

* Tax rate of 50 percent is assumed for simplification

+ Cash flow (in periods with no interest) is equal to:

((Revenues - (operating costs + depreciation)) x (1 - tax rate)) + depreciation except when costs plus depreciation exceeds revenues, in which case the tax rate (and therefore taxes) is zero.

period 1 to period 2, cash flow increases by 0.5. But once the firm becomes unprofitable (beyond period 5) the change in cash flow accelerates with cash flow declining by 1 in each period. In actual business practice, the tax carryover provisions would offset part of the decline in cash flow in unprofitable years.

The implication of the above discussion is that in cases where the baseline profitability is estimated as low, the profitability decline is being overstated. However, for high impact plants (Graph D-1), the overstatement does not appear to become significant until baseline profitability is in the 15 to 25 percent range. At that point, however, the after-pollution control cost IRR drops below zero and it is sufficient to assume that potential impacts are severe and further analysis is required.

For the light impact case, the profitability decline also begins to decline rapidly at five to 10 percent. In such cases, the plants are marginally profitable to begin with and while the profitability decline may be small, it may be the extra cost burden needed to encourage plant closures. In these cases, if the after control cost IRR is still positive and the profitability decline is small, concluding that the impact is slight is probably correct, especially since the profitability decline is probably being overstated.

The second point is that in the "normal" profitability range (that is, when profit margins are significantly greater than zero), the magnitude of the profitability decline gradually increases or decreases. To put it another way, the before control cost and after control cost IRR's either gradually converge or diverge. However, this divergence or convergence cannot be analytically predicted: it is case specific and depends on the configuration of cash flows over the modeled life of the plant. The change in the magnitude of the profitability decline is so slight in this range that it can be assumed that it does not affect the conclusions made in the impact analysis.

5. SENSITIVITY OF THE PROFITABILITY DECLINE TO THE CAPITAL COST ESTIMATE

A secondary issue is how the profitability decline responds to changes in the estimate of fixed investment in plant and equipment. In calculating the cash flow (CF) in each period, the following formula is used:

$$\begin{aligned} CF = {} & (1\text{-tax rate})\ (\text{Revenues} - \text{Costs} - \text{Depreciation}) + \text{Depreciation} \\ & + \text{Investment Tax Credit} - \text{Fixed Investment} \end{aligned}$$

Half the pollution control capital cost is subtracted from fixed investment in calculating the first year cash flow and half is subtracted in the second year. Since the cash flows in the first two years are weighted more heavily (i.e. discounted less heavily), the incremental costs of pollution control in the later years will have relatively less of an effect on the discounted cash flow if the estimate of fixed capital investment increases. This is demonstrated in Graph D-3. The scale along the abscissa is the multiplier applied to the best estimate of investment in plant and equipment. Thus, when the best estimate is used, the profitability decline is about five-tenths of a percentage point. When the capital cost is doubled, the decline drops to about three-tenths of a point; when the cost is halved, the decline increases to about one percentage point. This variation is relatively small. Further, the capital cost estimate is probably within 25 percent of the true value and the magnitude of the profitability decline is relatively constant within this range of capital investment.

6. SUMMARY AND CONCLUSION

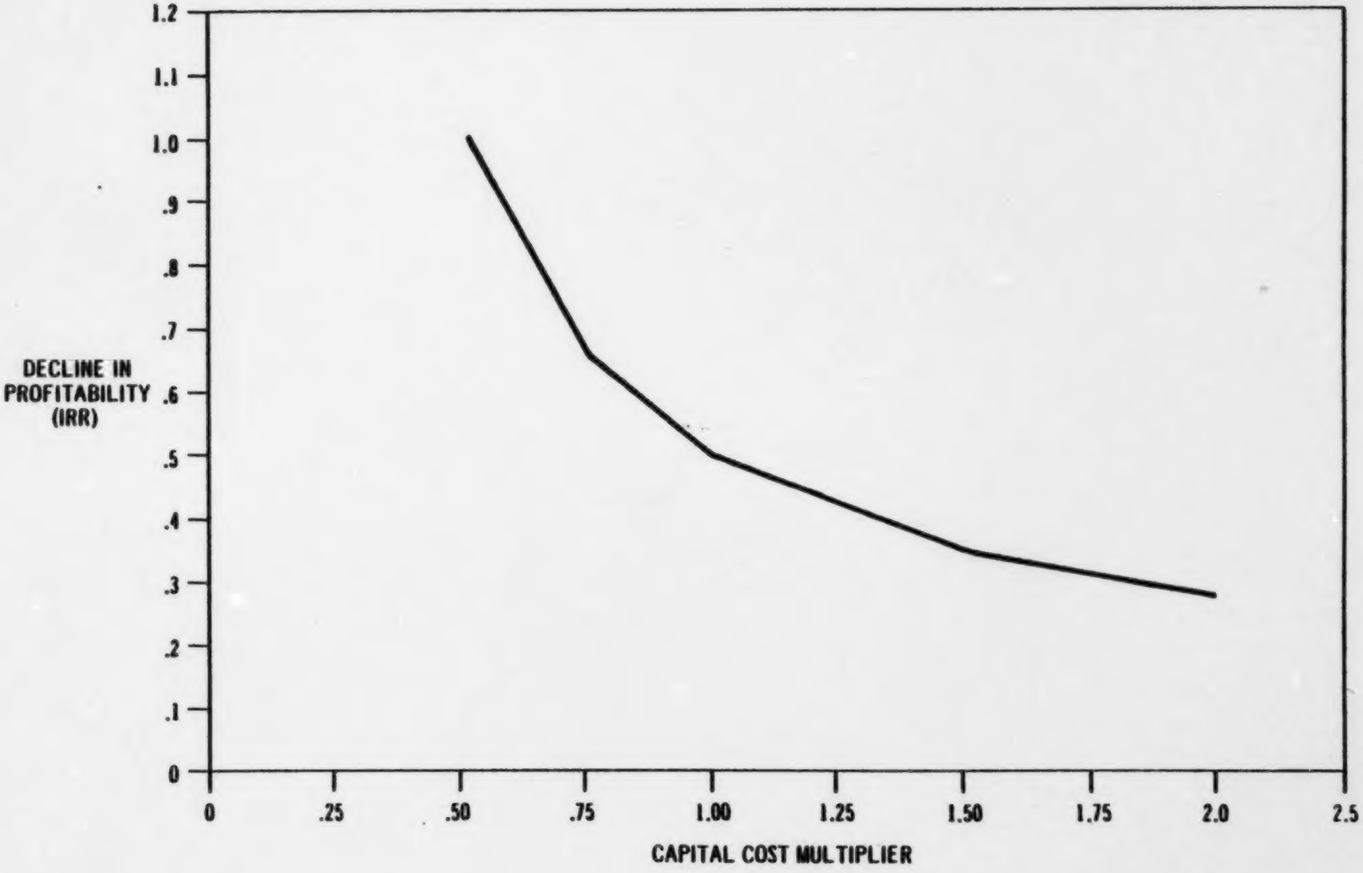
The sensitivity analysis reasonably demonstrates that the magnitudes of the profitability declines does not vary significantly with baseline profitability or capital investment costs. In cases of small declines in model plant profitability we can be confident that impacts on plants will be small, with the understanding that plants that are known to be marginal in the baseline case may have great difficulty absorbing pollution control costs of any magnitude.

In those cases where the profitability decline is large, additional research is always warranted. Particular attention should diverted to estimating current profitability levels through market research and contact with the industry.

GRAPH D–3

PROFITABILTIY DECLINE VS. CAPITAL COST

SODIUM HYDROSULFITE MODEL PLANT



APPENDIX E

REGULATORY FLEXIBILITY ANALYSIS

1. INTRODUCTION

The Regulatory Flexibility Act (Public Law 96-354), promulgated in September 1980, requires that a Regulatory Flexibility Analysis (RFA) be performed for rules which have a significant economic impact on a substantial number of small entities. Though an RFA is only required for regulations proposed after January 1, 1981 (guidelines for the Inorganic Chemicals Manufacturing Industry were proposed on July 24, 1980), an RFA was performed as an appendix to the economic impact analysis to further explore the impacts of the pollution control regulations on small plants in each subcategory.

The effluent guidelines and standards discussed in this report were proposed under the authority of the 1977 Clean Water Act (33 USC 1251) and in response to EPA's Settlement Agreement with the Natural Resources Defense Council. The Regulatory Flexibility Act, in Sections 603 and 604, requires a description of the economic impact of the rule on small entities and an analysis of alternative requirements that would minimize any significant economic impacts on small businesses. Through the RFA, the regulatory authority attempts to make the burden of any rule more equitable with respect to the size of the business. In this way, regulatory objectives can be met through regulatory options designed to minimize the economic impacts on small businesses.

Section 605(a) of the Act allows the RFA to be performed as part of other analyses conducted by EPA to avoid duplicative analysis. Therefore, the RFA for these regulations is included as a part of the Agency's economic analysis. A more detailed explanation of subcategory characterization, impact analysis methodology, and projected economic impacts can be found in the main body of this report.

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The Act defines a "small business" on the basis of the definition of a "small business concern" under section 3 of the Small Business Act (13 CFR Part 121). The definition is based on the number of employees within the firm or on the dollar volume of sales. However, both the Regulatory Flexibility Act and the Small Business Act recognize that a single definition may not be applicable to an entire industry due to the diversity of plant sizes. When the diversity of plant sizes within an industry warrants a more specific definition for the individual subcategory, both the Regulatory Flexibility and the Small Business Acts allow the establishment of a subcategory-specific small business definition based on parameters such as the industry output concentration ratio, the total number of concerns in the industry, and the size of the industry leaders.

Within the inorganic chemicals industry, the smallest plant production levels range from approximately 250 tons per year within the copper sulfate subcategory to 150,000 tons per year in the chloride-ilmenite segment of the titanium dioxide subcategory. Likewise, the largest plant production level within each subcategory ranges from approximately 2,400 tons per year to 228,000 tons per year. Because of the wide range in plant sizes, a small business definition based on production level was established for each subcategory.

In developing the model plant pollution control cost estimates for each subcategory, the technical contractor surveyed plants within each subcategory. From these surveys, the technical contractor determined a model plant size range based on the production levels of the actual plants in each subcategory. Small, medium, and large model plant sizes were then identified to reflect the actual plant size distribution within each subcategory. The small model plant size, reflecting the actual small plant production levels within each subcategory, is used as the "small business" definition for each subcategory.

2. ECONOMIC IMPACT ANALYSIS METHODOLOGY

Since it is often impractical to examine every plant in an industry, the financial analysis is based on model plants. The model plant parameters, including process type, production capacity, flow rates, and pollutant loads, were developed by the technical contractor based on surveys of actual plants in each subcategory. For each subcategory, small-, medium-, and large-size model plants were developed, based on estimated annual production. Pollution control costs were then developed by the technical contractor for each model plant size.

2.1 POLLUTION CONTROL TECHNOLOGY AND COSTS

Model plant annual control costs are calculated on a per ton basis and include the following:

- Operation and maintenance costs of the pollution control equipment
- Annualized capital costs of the pollution control investment.

Plant-specific capacity information, current production levels, and the technical contractor's estimate of control costs, industry profiles, and capacity utilization were also used to determine the per ton annual pollution control costs.

In addition, the chlorine (mercury and diaphragm cell) and chrome pigments subcategories will incur costs for compliance with the Resource Conservation and Recovery Act's Interim Status Standards (RCRA-ISS) promulgated in 1980. For these subcategories, the technical contractor developed RCRA-ISS compliance cost estimates including:

- Capital investment
- Initial costs
- Annual operating costs
- Total closure fund (to be built up over 20 years).

The impacts of the combined effluent control and RCRA-ISS costs* were then evaluated.

2.2 INDUSTRY IMPACTS

Four indicators were used to evaluate the impacts of pollution control costs for each subcategory:

- Price rise calculation
- Maximum potential profitability decline
- Price elasticity of demand
- Capital ratio.

2.2.1 Price Rise Calculation

The price rise analysis determines the magnitude by which the product price must increase to fully recover all annualized capital and operating pollution control costs. The assumption underlying the price rise analysis is that demand is completely inelastic, that the full price increase can be passed on to the consumer without resulting in any decline in physical sales volume.

2.2.2 Profitability Decline

The profitability analysis determines the degree to which profitability declines if no price pass-through is possible, i.e.; demand is infinitely elastic. Under this assumption, the manufacturer must absorb all pollution control costs in the form of reduced margins or increased losses. Baseline profitability is compared to profitability after pollution control equipment is installed using two indicators based on a discounted cash flow analysis for each model plant:

- Return on Investment (ROI) - yearly cash income divided by the total investment (calculated for each year in the analysis)

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*Note that the RCRA costs used in this analysis include baseline RCRA costs as well as the incremental costs associated with solid wastes generated by effluent treatment.

- Internal Rate of Return (IRR) - the discount factor used to yield a net present value of zero from the summation of the discounted cash flow in each year over the life of the plant.

2.2.3 Price Elasticity of Demand

Price elasticity of demand measures the ability of a firm to pass through a portion of its increased pollution control costs in the form of higher prices. This elasticity is a function of:

- The number, closeness, and relative cost of available substitutes
- "Importance" to the purchaser's budget
- Time period.

Price elasticity estimates were based on the market information developed in the subcategory characterization.

2.2.4 Capital Analysis

Pollution control facilities can require a significant investment, especially for smaller plants. To determine the relative burden of this one-time expense, the pollution control capital costs, estimated by the technical contractor, are compared to the fixed investment in plant and equipment.

2.2.5 Closure Analysis

The above four impact indicators are used in a closure analysis which identifies potentially "high impact" plants and closure probabilities.

Under the EPA's closure criteria, a model plant is considered a possible closure candidate if the demand is elastic, the price increase is greater than one percent, and the resulting profitability decline (in the case of no pass-through) is greater than one percentage point or greater than 10 percent of baseline (without pollution control) profitability. Price increases of one percent or less are assumed to have little effect on consumers or producers since a product price may fluctuate by at least one percent due to granting of discounts to volume purchasers and also due to short-term supply and demand surges and declines. Similarly, if a profitability decline of less than or equal to one percentage point and less than 10 percent of baseline profitability is assumed to have an insignificant impact on a plant's decision to curtail production or shut down. In this way, model plants that are potential closure candidates are screened for further analysis.

Once the closure criteria are applied to the model plants, the probability of closure for the corresponding actual plants is examined in detail based on plant-specific factors and actual market conditions. The detailed analysis evaluates the extent to which price pass-through is possible and the extent to which profitability will decline if immediate and complete price pass-through is not possible. Thus, the model plant analysis serves to identify potentially high impact plants (based on EPA's closure criteria); the plant closure projections are made only after detailed evaluation of actual plant and market conditions.

3. SUMMARY OF IMPACTS

The economic impacts of effluent control costs were analyzed for ten inorganic chemicals subcategories, covering 13 manufacturing processes. In addition, the combined impacts of effluent control and RCRA-ISS costs were analyzed for three of the 13 processes. Out of the 144 plants in the ten inorganic chemicals subcategories covered by effluent regulations, 69 plants corresponded to the small model plant size. Incremental effluent control costs were incurred by 53 of the 69 "small" plants. Only two subcategories, chrome pigments and titanium dioxide-sulfate process, were significantly affected by the effluent control costs. In the chrome pigments subcategory, four of the five small plants were projected for closure under the regulations. One or both of the small titanium dioxide-sulfate process plants were potential closure candidates. The additional impacts of RCRA-ISS costs on the chrome pigments subcategory were minimal compared to the effluent control cost impacts.

3.1 ALUMINUM FLUORIDE

- Small Model Plant Size: 17,500 tons per year (TPY)
- Number of Corresponding Plants: 2 (total production = 31,050 TPY)
- Total Number of Plants in Subcategory Affected by Regulations: 4 (total production = 100,050 TPY)
- Total Capital Investment in Pollution Control Equipment: None
- Required Additional Effluent Control Costs: None (For the aluminum fluoride subcategory, BAT regulations are based on BPT technology, already in place and operating for all plants in the subcategory.)
- Number of Projected Small Plant Closures: None

Both aluminum fluoride plants categorized as small plants are direct dischargers with BPT in place and operating. For this subcategory, BAT is equivalent to BPT. Since there will be no incremental costs above BPT required for compliance with BAT regulations, these regulations will have no impacts on the two small plants in the aluminum fluoride subcategory. Therefore, no small plant closures are projected. No further regulatory alternatives are considered for this subcategory because no significant impacts are projected.

3.2 CHLORINE

The two major manufacturing processes to produce chlorine use either mercury cells (20 percent of capacity) or diaphragm cells (74 percent of capacity). The remaining six percent of capacity is produced by processes that are not regulated by EPA. Pollution control cost impacts are different for each production process and therefore will be analyzed separately. In addition, the costs and impacts of compliance with RCRA-ISS requirements are included in the analysis.

3.2.1 Chlorine-Mercury Cell

- Small Model Plant Size: 21,000 tons per year (TPY)
- Number of Corresponding Plants: 8 (total production = 311,000 TPY)
- Total Number of Plants in Subcategory: 25 (total production = 1,209,000 TPY)
- Number of Small Plants Affected by Effluent Regulations: 7 (total production = 278,000 TPY)
- Number of Small Plants Affected by RCRA-ISS requirements: 8 (total production = 311,000 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $244,398
- Total Annualized Costs for Small Plants: $469,820
- Pollution Control Capital Costs as Percentage of Capital Investment: 0.23 percent
- Maximum Price Rise (all pollution control costs passed through to consumer): 1.54 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 0.21 percentage points or 24.42 percent of baseline profitability (based on ROI)
- Number of Projected Small Plant Closures: None

Eight plants, or approximately one-third of all mercury cell chlorine plants, correspond to the small model size. One small plant is an indirect discharger already in compliance with PSES limitations and will not incur incremental effluent control costs. The other seven plants are direct dischargers, all having BPT in place. These plants will incur the additional costs of BAT treatment. All eight mercury cell chlorine plants will incur additional hazardous waste disposal costs in order to comply with RCRA-ISS requirements.

Both the maximum profitability decline and the maximum price rise exceed the EPA closure criteria. Though the maximum profitability decline is less than one percentage point (0.21 percentage points), this decline corresponds to a 24.42 percent decrease of baseline profitability. Also, the maximum price rise exceeds the EPA closure criterion of a one percent change in price for compliance with BAT regulations (1.54 percent).

RCRA-ISS compliance costs increase the price and profitability impacts. Total investment costs in pollution control equipment for small plants including RCRA-ISS costs total $780,462 with annualized costs of $1,604,970. Pollution control capital costs represent a higher percentage of capital investment, increasing from 0.23 percent for BAT costs alone to 0.67 percent including RCRA-ISS costs. The maximum profitability decline increases from 0.21 percentage points to 0.67 percentage points or from 24.42 percent to 77.91 percent of baseline profitability. The impact of RCRA-ISS costs on the required price rise is 4.85 percent, an increase from 1.54 percent to pass through BAT costs alone. Implementing a one to five percent increase in price would be difficult given the current market conditions of excess capacity and slow demand growth.

Detailed analysis shows that no small mercury cell chlorine plants are projected to close as a result of BAT and RCRA-ISS costs. Almost two-thirds of chlorine production is used in the manufacture of more profitable downstream products. End users of chlorine-containing products would be cushioned from the full impact of the projected one to five percent price increase. Further, the mercury cell process produces sodium hydroxide (caustic soda) as a co-product. Demand for caustic soda is currently very strong, and it may be possible to at least partially recover effluent control and RCRA-ISS costs through caustic soda price increases.

Because the impacts of effluent control and RCRA-ISS costs have the potential of being mitigated, no small plant closures are projected for this subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.2.2 Chlorine-Diaphragm Cell

- Small Model Plant Size: 21,000 tons per year (TPY)
- Number of Corresponding Plants: 10 (total production = 320,000 TPY)
- Total Number of Plants in Subcategory: 36 (total production = 6,367,000 TPY)
- Number of Small Plants Affected by Effluent Regulations: 10 (total production = 320,000 TPY)
- Number of Small Plants Affected by RCRA-ISS Regulations: 3 (total production = 42,000 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $652,740
- Total Annualized Costs for Small Plants: $707,200
- Pollution Control Costs as Percentage of Capital Investment: 0.47 percent
- Maximum Price Rise (all pollution control costs passed through to consumers): 2.01 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 0.25 percentage points or 8.96 percent of baseline profitability
- Number of Projected Small Plant Closures: None

Ten diaphragm cell chlorine plants correspond to the small model plant size. All ten plants are direct dischargers, and all are meeting BPT effluent limitations. Therefore, these plants will incur only the incremental costs of compliance with BAT effluent limitations. Three of these small plants use graphite anodes and will also incur additional hazardous waste disposal costs in order to comply with RCRA-ISS requirements.

The maximum profitability decline is less than the EPA closure criterion of a one percentage point change in profitability and a ten percent decrease in baseline profitability (0.25 percentage points or 8.96 percent). However, the maximum price rise exceeds the EPA closure criterion of a one percent change in price to pass through BAT costs (2.01 percent).

The incremental impacts of RCRA-ISS costs on price and profitability are minimal. It is assumed the plants will dispose of their wastes in an off-site landfill; therefore no capital or closure fund costs will be incurred for compliance with RCRA-ISS requirements. Total pollution control investment costs for the three small plants incurring RCRA-ISS costs are $195,922 with total annualized costs of $103,320. The maximum profitability decline with RCRA-ISS costs added to BAT increases from 0.25 percentage points to 0.29 percentage points or from 8.96 percent to 10.39 percent of baseline profitability. The additional RCRA-ISS costs increase the maximum price rise from 2.01 percent to 2.24 percent.

As explained in Section 3.2.1 on mercury cell chlorine plants, while price increases required to recover combined effluent control and RCRA-ISS costs exceed one percent, chlorine producers should be able to pass through their cost increases in final product prices. If cost pass-through is not immediate and complete, resulting profitability impacts will be minimal, with a profitability decline of less than 0.3 percentage points or 8 to 10 percent of baseline profitability.

Because the impacts of effluent control and RCRA-ISS costs are minimal or have the potential of being mitigated, no small plant closures are projected for this subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.3 CHROME PIGMENTS

- Small Model Plant Size: 1,650 tons per year (TPY)
- Number of Corresponding Plants: 5 (total production = 6,000 TPY)
- Total Number of Plants in Subcategory: 12 (total production = 72,500 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $1,036,954

- Total Annualized Costs for Small Plants: $676,950
- Pollution Control Capital Costs as Percentage of Capital Investment: 37.03 percent
- Maximum Price Rise (all pollution control costs passed through to consumers): 14.03 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 17.92 percentage points or over 100 percent of baseline profitability (based on ROI)
- Number of Projected Small Plant Closures: One (production line only)

For this subcategory, BAT and PSES limitations are based on BPT and, therefore, the effluent control costs for direct and indirect dischargers are equivalent. None of the small chrome pigments plants have control equipment in place. Therefore, the analysis addressed the impact of effluent control costs required for compliance with BAT/PSES regulations. In addition, the impacts of the combined costs of compliance with BAT/PSES and RCRA-ISS were also examined.

The cost of installing and operating BAT/PSES removal level equipment would impose significant impacts on the small chrome pigments plants. The capital requirements of complying with pollution control regulations represent approximately 37 percent of the present fixed investment of the plant and could pose severe problems to small plants. To pass through the costs of BAT/PSES regulations, small chrome pigments plants would require a 14.03 percent price rise. Alternatively, if no price pass-through is possible, plants would suffer a 17.92 percentage point profitability decline which represents over 100 percent of baseline profitability. Thus, according to EPA's closure criteria, the significant impacts of effluent control regulations would result in possible plant closures for all five small chrome pigments plants.

The incremental price and profitability impacts of RCRA-ISS costs are relatively small in comparison to the impacts of effluent control costs.

The price of pigments would have to be raised an additional 1.33 percent. Similarly, the incremental decline in profitability (1.87 percentage points or 17.07 percent of baseline profitability) would be small relative to the large profitability impacts of BAT/PSES costs.

Small plants would suffer more severe impacts from effluent regulations than larger plants. Larger plants would require a price rise of 5.54 to 8.63 percent compared to the 14.03 percent price rise required for smaller plants. Small plants would suffer a 17.92 percentage point profitability decline or a decrease of over 100 percent of baseline profitability while larger plants' profitability decline ranges from 9.79 to 11.67 percentage points or 35.78 percent to 54.38 percent of baseline profitability. While all plants in the subcategory could be projected to close according to EPA's closure criteria, the small baseline profit margins and severe impacts on small plants would make them the most likely candidates for shutdown.

Two factors will constrain any price increase by small plants: the potential market shift to organic pigments and competition from imports. While organic pigments are currently much higher in price, some pigment users are now choosing them to avoid the current and anticipated health and regulatory problems associated with many lead-containing chrome pigments. A price increase in chrome pigments will only accelerate this move to organics. Imports also constrain price increases. Imports are currently very cost competitive and will become even more so with further domestic price increases. Thus, profit margins and profitability will decline. Given the low baseline profitability for the small plants, even a small profitability decline could encourage them to cease operations.

Due to the high control costs and capital requirements of BAT/PSES and RCRA-ISS regulations, difficulty in achieving complete pass-through of cost increases, and low baseline profitability, imposition of the effluent regulations could result in plant or production line closures, as discussed below.

One small plant is involved solely in chrome oxide green production, and therefore will not be affected by OSHA's further limitations on worker exposure to lead and will not face the high costs of compliance with these regulations. Further, demand for chrome oxide green is much stronger than for the other chrome pigments, and sustained demand strength will probably allow this small producer to pass-through part of the control costs to customers. Therefore, it is less likely to close than the other small chrome pigments plants which must comply with both OSHA and EPA regulations.

Three small plants were projected to close due to these regulations. Because of these severe impacts, and the small size of the plants (approximately 1000 tons of pigment annually), the final regulations include an exemption from categorical pre-treatment standards for plants producing less than 2200 tons annually.

The remaining small plant is too large to qualify for the exemption. Therefore, a chrome pigment production line closure is projected for this plant. Chrome pigments account for only a small portion of the plant's total production, and the plant is therefore expected to remain open.

This plant accounts for roughly three percent of subcategory production and employment (20 workers). The facility is owned by a large chemical concern, raising the possibility that the employees could be reassigned to other operations.

3.3.1 Other Subcategory Regulations

The chrome pigments subcategory is also subject to OSHA regulations concerning air quality in production facilities. OSHA regulations call for a reduction in lead and chromium dust levels to 50 micrograms per cubic meter of air in both end market workshops (i.e., paint manufacturing plants) and pigment production facilities. In addition, producers will face strict limits on the discharge of hexavalent chromium, a known carcinogen, from production facilities.

The impacts of OSHA regulations are uncertain. However, these regulations, particularly those concerning lead-containing dusts, will raise the price of chrome colors and cause some substitution with organic colors. Chrome oxide green and zinc yellow contain no lead and should be affected less severely by OSHA regulations.

3.4 COPPER SULFATE

- Small Model Plant Size: 2,300 tons per year (TPY)
- Number of Corresponding Plants: 16 (total production = 30,100 TPY)
- Total Number of Plants in Subcategory: 16 (total production = 30,100 TPY)
- Number of Projected Small Plant Closures: None

All plants in this subcategory correspond to the small model plant size.* EPA has determined that no plants in this subcategory will incur compliance costs under this rulemaking:

- All 15 direct dischargers already have BPT in place, and BAT has been set equal to BPT for this subcategory.
- Pretreatment standards for indirect dischargers were promulgated previously. The current rulemaking revises the limitations to equal BAT, but does not change the technology basis or the compliance costs. Therefore, while the single indirect discharger in the industry may not have treatment in place, the compliance cost it will have to incur is attributable to an earlier rulemaking (40 CFR 415.374). There are no additional compliance costs associated with the current regulation.

Accordingly, these regulations will have no economic impact on the subcategory.

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*For this subcategory, the technical contractor developed only one model size with annual production of 2,300 tons per year.

3.5 HYDROGEN CYANIDE

- Small Model Plant Size: 35,000 tons per year (TPY)
- Number of Corresponding Plants Affected by Effluent Regulations: 5 (total production = 78,325 TPY)
- Total Number of Plants in Subcategory: 11 (only 7 are affected by the effluent regulations with total production = 143,325 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $948,750
- Total Annualized Costs for Small Plants: $419,039
- Pollution Control Costs as Percentage of Capital Investment: 0.5 percent
- Maximum Price Rise (all pollution control costs passed through to consumers): 0.81 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 0.27 percentage points or 1.24 percent of baseline profitability
- Number of Projected Small Plant Closures: None

Only primary process hydrogen cyanide manufacturers will be affected by the effluent regulations. Of the seven primary process manufacturers, five plants correspond to the small model size category. All five small plants are direct dischargers having BPT in place and operating. Therefore, the economic impact analysis assessed the additional costs required by all five small plants to meet BAT effluent removal levels.

Both the required price rise (0.81 percent) and maximum profitability decline (0.27 percentage points or 1.24 percent of baseline profitability) are less than the EPA closure criteria of a one percent change in price, and a one percentage point or ten percent decline in profitability. Based on the EPA's closure criteria, the cost of complying with BAT regulations will have minimal impact on small hydrogen cyanide plants. Therefore, no small plant closures are projected for this subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.6 HYDROGEN FLUORIDE

- Small Model Plant Size: 21,000 tons per year (TPY)
- Number of Corresponding Plants: 6 (total production = 77,520 TPY)
- Total Number of Plants in Subcategory: 9 (total production = 227,400 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $409,860
- Total Annualized Costs for Small Plants: $172,094
- Pollution Control Costs as Percentage of Capital Investment: 0.6 percent
- Maximum Price Rise (all pollution control costs passed through to consumers): 0.34 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 0.52 percentage points or 11.61 percent of baseline profitability
- Number of Projected Small Plant Closures: None

Of the nine hydrogen fluoride manufacturers, six plants correspond to the small model size category. All six plants are direct dischargers having BPT in place and operating. Therefore, the economic impact analysis assessed the impact of the additional costs required by all six small plants to meet BAT effluent removal levels.

The required price rise (0.34 percent) is less than the EPA closure criterion of a one percent change in price. However, the maximum profitability decline of 0.52 percentage points represents an 11.61 percent decrease in baseline profitability, exceeding the EPA closure criterion of a ten percent change in baseline profitability. Further analysis shows demand for hydrogen fluoride to be moderately price elastic; because demand is only moderately price elastic and the required price rise is minimal (0.34 percent), a complete price pass-through of pollution control costs is likely. This price pass-through should mitigate any profitability declines.

Based on the EPA's closure criteria, the costs of complying with effluent regulations will have minimal impacts on small hydrogen fluoride plants. Therefore, no small plant closures are projected for this subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.7 NICKEL SULFATE

- Small Model Plant Size: 990 tons per year (TPY)
- Number of Corresponding Plants: 10 (total production = 4,518 TPY)
- Total Number of Plants in Subcategory: 11 (total production = 7,032 TPY)
- Number of Projected Small Plant Closures: None

Ten of the 11 plants in the subcategory correspond to the small model size category. Five plants are direct dischargers and five are indirect dischargers. EPA has determined that no plants in this subcategory will incur compliance costs under this rulemaking:

- All five small direct dischargers already have BPT in place, and BAT has been set equal to BPT for this subcategory.
- Pretreatment standards for indirect dischargers were promulgated previously. The current rulemaking revises the limitations to equal BAT, but does not change the technology basis or the compliance costs. Therefore, while one of the five small direct dischargers may not have treatment in place, the compliance costs it will have to incur are attributable to an earlier rulemaking (40 CFR 415.374). There are no additional compliance costs associated with the current regulation.

Accordingly, these regulations will have no economic impact on the subcategory.

3.8 SODIUM BISULFITE

- **Small Model Plant Size: 5,000 tons per year (TPY)**
- **Number of Corresponding Plants: 3 (total production = 13,928 TPY)**
- **Total Number of Plants in Subcategory: 7 (total production = 66,960 TPY)**
- **Total Investment Costs in Pollution Control Equipment for Small Plants: $144,174**
- **Total Annualized Costs for Small Plants: $92,337**
- **Pollution Control Costs as Percentage of Capital Investment: 6.90 percent**
- **Maximum Price Rise (all pollution control costs passed through to consumers): 8.97 percent**
- **Maximum Profitability Decline (all pollution control costs absorbed by the firm): 5.41 percentage points or 64.02 percent of baseline profitability (based on ROI)**
- **Number of Projected Small Plant Closures: None**

Three of the seven plants in the subcategory correspond to the small model size category. Two small plants are direct dischargers with BPT in place and operating. For this subcategory, BAT and PSES are equivalent to BPT. Since there will be no incremental costs above BPT, BAT regulations will have no impacts on these two plants.

One small sodium bisulfite plant is an indirect discharger without pretreatment equipment in place. Therefore, the economic impact analysis addressed the impacts of pretreatment costs, which are equivalent to BPT removal costs, on this indirect discharger.

The maximum price rise (8.97 percent) and the maximum profitability decline (5.41 percentage points or 64.02 percent of baseline profitability) both significantly exceed the EPA's closure criteria of a one percent change in price, and a one percentage point or ten percent change in profitability.

Based on EPA's closure criteria, the model plant analysis shows that a small sodium bisulfite plant currently without BPT in place would be projected for closure. However, further analysis shows that the actual small plant is not likely to close.

While sodium bisulfite is not a critical input to any process, its major market, photographic processing chemicals, is very secure because no substitutes exist which are as convenient and inexpensive. The same applies to the demand situation in its other major end-use, food processing. This implies relatively inelastic demand, allowing for increased costs to be passed on to the consumer without a significant loss of demand.

Four other factors should mitigate the impacts on this plant:

- The indirect discharger should currently be operating with a slight cost advantage since the other plants in the industry have been required to operate pollution control equipment under the promulgated BPT regulations. Since the indirect discharger will need to incur the same costs (plus capital cost inflation), the plant's cost and profit levels will again be in line with the industry-wide levels.

- If the plant does require a price increase to remain competitive, price pass-through is likely. The plant enjoys a regional market advantage since it is one of two bisulfite producers on the West Coast. The other West Coast producer is very small, and it is unlikely to expand its bisulfite production sufficiently to penetrate the indirect discharger's existing markets.

- The plant is insulated from competition from East Coast producers because of transportation costs. The plant's ability to recover its costs through a price increase will depend on the magnitude of the delivery costs required to ship bisulfite from East Coast producers to West Coast markets relative to the pollution control costs to be incurred by the plant. Based on current price levels, the required price increase (8.97 percent) would raise the affected plant's price from $490/ton to $534/ton. Transportation costs to the West Coast (via rail) would raise the East Coast price of $450/ton to $615/ton. Given this delivered selling price comparison, it appears that the plant would be able to pass through most if not all of its pollution control costs.

- EPA has subsequently determined that the model control system used in this analysis is oversized. The costs of compliance and associated economic impacts are therefore overstated.

These factors suggest that pretreatment standards will not cause severe problems for the indirect discharger. Therefore, no small plant closures are projected for the entire subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.9 SODIUM DICHROMATE

- Small Model Plant Size: 22,000 tons per year (TPY)
- Number of Corresponding Plants: 1 (total production = 26,186 TPY)
- Total Number of Plants in Subcategory: 3 (total production = 156,800 TPY)
- Total Capital Investment in Pollution Control Equipment: None
- Required Additional Effluent Control Costs: None (For the sodium dichromate subcategory, BAT regulations are based on BPT technology, already in place and operating for all plants in the subcategory.)
- Number of Projected Small Plant Closures: None

Only one plant in the sodium dichromate subcategory corresponds to the small model size category. BPT effluent limitations are in effect for all sodium dichromate manufacturers. Therefore, the economic impact analysis assumed that BPT equipment was in place and operating for this plant. For this subcategory, BAT is equivalent to BPT. Since there will be no incremental costs above BPT for compliance with BAT regulations, these regulations will have no impact on the one small sodium dichromate plant. Therefore, no small plant closures are projected for this subcategory. No further regulatory alternatives are considered for this subcategory because no significant impacts on small plants are projected.

3.10 TITANIUM DIOXIDE

Titanium dioxide is manufactured by three processes: sulfate, chloride, and chloride-ilmenite. Pollution control cost impacts are different for each production process and will be analyzed separately.

3.10.1 Titanium Dioxide - Sulfate Process

- Small Model Plant Size: 35,000 tons per year (TPY)
- Number of Corresponding Plants: 2 (total production = 73,720 TPY)
- Total Number of Plants in Subcategory: 4 (total production = 204,440 TPY)
- Total Investment Costs in Pollution Control Equipment for Small Plants: $5,345,454
- Total Annualized Costs for Small Plants: $6,457,872
- Pollution Control Capital Costs as Percentage of Capital Investment: 3.17 percent
- Maximum Price Rise (all pollution control costs passed through to consumers): 9.52 percent
- Maximum Profitability Decline (all pollution control costs absorbed by the firm): 4.64 percentage points or 61.62 percent of baseline profitability
- Number of Projected Small Plant Closures: None

Of the four titanium dioxide plants using the sulfate process, two plants correspond to the small model size. Both plants will incur BAT effluent control costs.

The technical contractor has estimated that sales of the gypsum by-product, generated by effluent treatment equipment, could reduce BAT costs for sulfate process titanium dioxide plants by $22 per ton of titanium dioxide produced. Though it is possible that the total volume of gypsum by-product may be sold, the price rise and profitability change analysis assumes that no gypsum credit is received by the manufacturer in order to determine the maximum impact of effluent control costs.

The model plant analysis shows that small sulfate process titanium dioxide plants will suffer significant impacts from the costs of BAT limitations. The required price rise (9.52 percent) and maximum profitability decline (4.64 percentage points or 61.62 percent of baseline profitability) significantly exceed the EPA closure criteria of a one percent change in price, and a one percentage point or ten percent change in profitability. Even with a full gypsum credit, the price and profitability impacts are significant.

The BAT cost impacts on small titanium dioxide plants are much greater than on larger plants. Large plants would require a 2.11 percent price rise compared to the 9.52 percent required for small plants. Also, large plants incur a profitability decline of only 0.75 percentage points (6.86 percent of baseline profitability) compared to the 4.64 percentage points (61.62 percent of baseline profitability) decline for small plants. Large plants, better able to absorb or pass through the BAT costs, are not projected to close. The impacts on small plants, which are less able to absorb or pass through the control costs, indicate that plant closure is possible for both small plants.

However, even given these indications of substantial price and profitability impacts it is unlikely that either small plant will close. One of these two small producers has already made a partial investment in waste treatment facilities which is not reflected in the analysis; therefore, the price and profitability impacts for this plant are overstated. Moreover, despite the additional costs that would be incurred to reach full compliance, the producer has publicly announced that it plans to continue production and foresees a long-term market for the anatase grade pigment produced by the sulfate process (Chemical Marketing reporter, December 24, 1979). The final regulation also incorporates specific changes requested by this manufacturer. Given these circumstances, it seems unlikely that the plant would close.

The other plant has recently signed a court agreement to meet limitations equal to those set forth in this final regulation and has agreed to install wastewater treatment controls and continue production in compliance with the regulation. Accordingly, continued operation of the plant appears likely.

In summary, although the quantitative economic indicators suggest possible closure of these two plants, their actual circumstances are such that closures appear highly unlikely.

3.10.2 Titanium Dioxide - Chloride

- Small Model Plant Size: 18,500 tons per year (TPY)
- Number of Corresponding Plants: 1 (total production = 23,100 TPY)
- Total Number of Plants in Subcategory: 6 (total production = 184,030 TPY)
- Required Additional Effluent Control Costs: None (For the chloride process segment of the titanium dioxide subcategory, BAT regulations are based on BPT technology, already in place and operating for all plants).
- Number of Projected Small Plant Closures: None

All chloride process titanium dioxide plants are direct dischargers with BPT installed and operating. For this subcategory, BAT is equivalent to BPT. Therefore, no incremental costs above BPT are required for compliance with BAT regulations. Accordingly, no impacts or plant closures are projected for chloride process titanium dioxide plants.

3.10.3 Titanium Dioxide - Chloride-Ilmenite

- Small Model Plant Size: 150,000 tons per year (TPY)
- Number of Corresponding Plants: None
- Total Number of Plants in Subcategory: 3 (total production = 419,650 TPY)

No titanium dioxide plants, using the chloride-ilmenite process, are categorized as small plants. Therefore, no further analysis of regulatory impacts or alternatives is undertaken for this segment of the titanium dioxide subcategory.

APPENDIX F

SOCIAL COSTS OF EFFLUENT GUIDELINE REGULATIONS

1. BACKGROUND

Executive Order 12291, released in February 1981, is intended to ensure that regulatory agencies evaluate the need for taking regulatory action, consider a wide range of alternatives, and select the regulatory alternative in light of their knowledge of the costs and benefits of the regulation. Toward this end, the Order establishes a set of regulatory reform and review procedures, including a requirement that regulations be analyzed in terms of their total cost to society, as well as the direct compliance costs.

This appendix presents estimates of the social costs associated with the effluent guideline regulations. Social costs may be defined as:

> The value of goods and services lost by a society resulting from the use of resources to comply with a regulation, the use of resources to implement a regulation, and reductions in output due to compliance.

2. METHODOLOGY

In many cases, including the inorganic chemicals regulations, the annualized direct compliance (or direct resource) costs of a regulation are effectively equal to social costs. The direct compliance costs associated with the effluent guidelines regulations consist of an initial capital investment and annual operations and maintenance (O&M) costs. Under EPA's current methodology, annual resource costs are equal to the annualized present value of the direct compliance costs extended perpetually. In the simplified calculation used for this analysis:

Annual Social Costs = (0.1 x CI) + O&M

where: CI = capital investment

O&M = operations and maintenance costs

0.1 = capital recovery factor for a 10% real perpetual return

Note: 10% real rate specified by the Office of Management and Budget

In addition to the real resource costs, other, less significant costs which could be applicable include:

- Government Administrative Costs: The incremental effort to monitor and enforce these regulations is believed minor compared to total social costs.
- Deadweight Welfare Loss: Losses which occur due to the net change in consumer and producer surplus resulting from a decrease in production. The production impact of these regulations is minor, so this loss is insignificant.
- Adjustment Costs for Unemployed Resources: Unemployment caused by the regulations is expected to be small, and is discussed in the report.

3. RESULTS

Table F-1 presents the annual social costs for all subcategories incurring incremental effluent guidelines BAT/PSES costs. The industry-wide total of $19.0 million is primarily accounted for by three subcategories: titanium dioxide-sulfate process (38.4 percent of the total), chrome pigments (30.0 percent), and chlorine (25.8 percent). The remaining five subcategories were responsible for social costs of only $1.1 million, or 5.8 percent of the total.

TABLE F-1

SOCIAL COSTS

(Millions of Dollars)

Subcategory	Annual Social Costs	Percent of Total
Chlorine - Mercury Process	1.2	6.3
Chlorine - Diaphragm Process	3.7	19.5
(Total Chlorine)	(4.9)	(25.8)
Chrome Pigments	5.7	30.0
Copper Sulfate	0.0	0.0
Hydrogen Cyanide	0.7	3.7
Hydrogen Fluoride	0.3	1.6
Nickel Sulfate	0.0	0.0
Sodium Bisulfite	0.1	0.5
Titanium Dioxide - Sulfate Process	7.3	38.4
TOTAL	19.0	100.0

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